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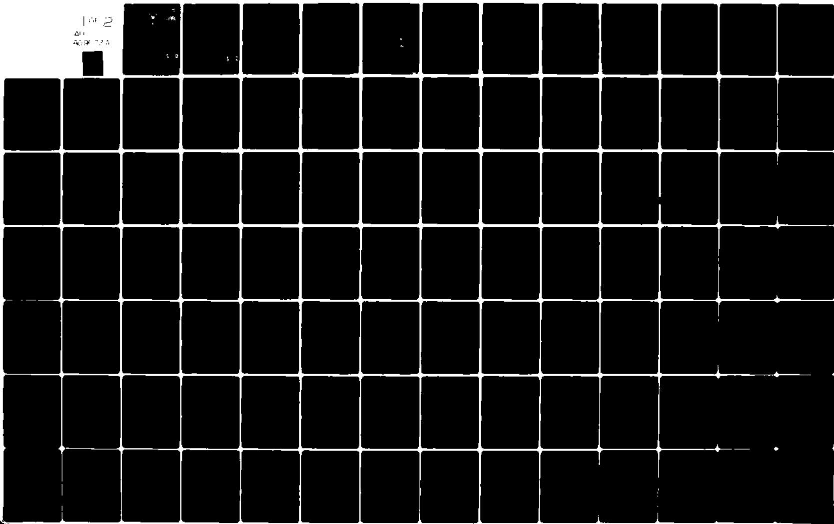

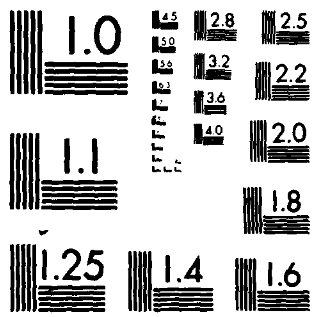

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A STUDY AND MODEL OF THE NONCOMBATANT EVACUATION OPERATION IN THE FEDERAL REPUBLIC OF GERMANY

Harry W. Gullett, Captain, USMC
Thomas N. Stiver, Captain, USAF

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Computer simulation is employed to examine the existing Noncombatant Evacuation Operation as it removes military dependents and other American Nationals from the Federal Republic of Germany in the event of conventional war. The model traces the flight of evacuees from their hotels and homes to the United States on military and civilian aircraft. The model examines the relationships between the number of transportation assets dedicated to moving evacuees, the weather, and the number of aircraft dedicated to removing evacuees to the U.S. The study uses the civilian airport at Munich and the military airfield at Rhein-Main as representative evacuation ports, detailing the effects of sixty policy options of transportation and aircraft on the time required to evacuate a fixed population. The results present the time required under each policy to successfully evacuate the fixed populations and the probable number of Americans rerouted to avoid capture. The results also indicate a requirement for further tests of the actual system. Schematic drawings of the networks, the computer programs, and a glossary of symbols/terms are included to allow the reader to replicate or expand the network to test additional constraints or verify the authors' conclusions.

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A STUDY AND MODEL OF THE NONCOMBATANT EVACUATION OPERATION IN THE FEDERAL REPUBLIC OF GERMANY

A Thesis

Presented to the Faculty of the School of Systems and Logistics

of the Air Force Institute of Technology

Air University

In Partial Fulfillment of the Requirements for the

Degree of Master of Science in Facilities Management

By

Harry W. Gullett, BA
Captain, USMC

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June 1980

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This thesis, written by

Captain Harry W. Gullett

and

Captain Thomas N. Stiver

has been accepted by the undersigned on behalf of the faculty of the School of Systems and Logistics in partial fulfillment of the requirements for the degree of

MASTER OF SCIENCE IN FACILITIES MANAGEMENT

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Thomas D. Clark, Jr.

COMMITTEE CHAIRMAN

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CHAPTER I

INTRODUCTION

The United States maintains numerous military installations in the Federal Republic of Germany (FRG), as well as forces in West Berlin. There are estimated to be over 150,000 military dependents living on and around those installations (14:14). There are also estimated to be 600,000 other American nationals in the FRG, including State Department employees and their families, businessmen, contractor personnel, and tourists (7:21). Plans exist for evacuating any or all of the above in the event of natural disaster, political expediency, or acts of war. The plans call for evacuating the noncombatants to another European country, or back to the United States, depending on which situation has occurred. Congress has repetitively asked the Department of Defense (DOD) how long such an operation would take to complete (24). An accurate and realistic time estimate could not be computed due to the absence of an accurate population count on the one hand, and the lack of a device for collating variable inputs into an answer on the other. The estimates presented to Congress have varied from several days to a few months (35). Research to date indicates that neither the DOD nor Headquarters, Military Airlift Command (MAC) have devised a replicable method for correlating varying levels of population, fuel stockpiles, weather conditions, and other key

factors to derive those estimates presented to Congress (12; 16).

The lack of a means for accurately predicting the time requirements for evacuating the noncombatant population has possibly played a major role in Congress' decision to limit the world-wide number of military dependents allowed overseas to 325,000 effective 30 September 1980 (4:10). The uncertainty about evacuation time could prove to be a potentially significant stumbling block to the operational commanders, who need to know how fast their commands can be cleared for action. Other plans for the bedding-down of augmentation forces call for the use of facilities occupied by noncombatants. There is also the concern that the presence of noncombatants (especially dependents) in a combat area will affect adversely the morale and combat effectiveness of the troops stationed in the FRG. Lacking a study which accurately predicts how long the evacuees will be queued up at the aerial ports awaiting embarkation, the commanders of those aerial ports have no feasible way of planning how much food, water, shelter, or medical supplies should be allocated for use by the evacuees. In addition, a fairly complete model of the evacuation system may be useful to Department of Defense planners in testing the adequacy of aircraft fuel supplies, as well as intra-theater airlift capability and other factors associated with a large-scale operation. The uncertainties surrounding the noncombatant problem provide sufficient justification to initiate several separate studies into the various doubtful areas. Are there sufficient fuel reserves to turn around civilian aircraft as well as military

aircraft used in a large-scale evacuation effort? Can the base functions at the aerial ports handle large numbers of evacuees? These and other questions should be tested in a model to determine their impact before attempting such a large operation. There are other benefits in using a model besides the advantage of answering these questions by manipulating a model instead of disrupting the normal everyday operational environment. The massive manhour requirements and expense associated with a live test of the actual Noncombatant Evacuation Operation (NEO) system can be avoided by using a model. We can also explore many alternatives in a model that would be difficult to incorporate in a live test, such as blocking portions of the surface transportation networks or shutting down specific aerial ports. It is rather easy to compress time in a simulation model and speed up or slow down various phenomenon to facilitate the concentration of effort into one or more areas. Another justification for using a model is that the analysis of the system through the use of mathematical formulas alone might be difficult to translate into easily communicated results to people with limited statistical backgrounds (27:10-12). Perhaps of more critical importance at this time is the provision of some documented evidence to verify or rebutt Congress' decision to limit the number of military dependents allowed overseas (21:2).

Problem Statement

The emphasis in current military planning calls for the aerial evacuation of the American noncombatant population from

bases in the FRG via the air fleet bringing augmentation forces and supplies to those bases. A means for accurately predicting the time required to complete such an evacuation has not been found to exist.

Research Objective

The purpose of this research is to develop a model for estimating the time required for a full-scale evacuation and to assist top-level management in the military in making the best possible decisions concerning the allocation of the airlift resources required to effect an evacuation. This will be done by answering the following research questions.

Research Questions

1. What is the structure of the existing Noncombatant Evacuation Operation (NEO) system?

2. What are the interactions between and among the major subsystems?

3. Which subsystem(s) is (are) most sensitive to change?

Literature Review

Background. The evacuation of American nationals from foreign countries during natural or manmade crisis is the responsibility of the State Department. This responsibility has been exercised as recently as 1979 in Uganda, Zaire, and Iran (8; 12). According to an article in the Air Force Times, the State Department has relinquished this responsibility to DOD in Cuba, the Panama Canal Zone, West Berlin, and the Federal

Republic of Germany (FRG) (10). The President has delegated the responsibility for carrying out an evacuation in these areas to the respective senior military commanders. The Commander-in-Chief, United States Forces in Europe (USCINCEUR) has the overall responsibility for evacuating noncombatants in West Berlin and the FRG. The military identifies this mission as the Noncombatant Evacuation Operation (NEO) and has promulgated numerous plans from the Major Command level to supporting plans at the base level. Official policy defines NEO as an operation which is directed by the President to accomplish ". . . the movement of civilians and designated military personnel from the area in which an emergency has been declared by competent U.S. authority [34:1]."

The FRG is divided into three autonomous NEO regions administered by V Corps, VII Corps, and the 21st Support Command of U.S. Army, Europe (USAREUR). These regions are further subdivided into NEO Zones, administered by the designated Zone Commander (usually the commander of the largest base or military installation within the zone). Each Zone Commander issues implementing instructions to the bases and tenant units within his Zone; the instructions promulgated by the 86th Tactical Fighter Wing (TFW) are considered representative and will be referenced throughout the body of this research (33).

The 86th TFW instructions require each organizational Commander to appoint an officer or NCO as the unit's NEO representative. This individual's duties include the training

of new arrivals, briefing of their dependents concerning the Command's NEO policies and procedures, and aiding their unit personnel in the preparation of their evacuation documents (1; 6 ; 33). In addition, this representative is tasked with maintaining a current roster of command-sponsored dependents and approved waivers designating military personnel as non-combatants for the purpose of escorting their minor dependents to safety (34). The additional duty NEO personnel are responsible for preparing and submitting a semi-annual report on NEO population counts and training status to Zone/Regional Headquarters (33). These tasks are accomplished as additional duties without benefit of extra clerical support. During an evacuation operation, the NEO personnel are used throughout every phase, from alerting the noncombatant population to processing the evacuees for boarding evacuation aircraft (28). The supporting local plans are inspected during the annual Inspector General visits, but their practicality is a function of local command interest, individual initiative, and the size of the units involved. The local plans appear similar in function to the crisis relocation plans of Soviet and American Civil Defense authorities (23; 25; 37; 38).

Civil defense preparedness in the United States is under the office of the President, who has delegated the organizational responsibilities to the Defense Civil Preparedness Agency (DCPA). The DCPA is charged with disaster relief, civil defense, and crisis relocation; the latter function involves the movement of unprotected civilian populations

from high risk cities into rural sanctuaries, utilizing the existing road, rail, river, and air transportation networks. To test the adequacy of its plans, the Agency has prepared several excellent studies using queueing models and computer simulations. These studies predict the effects of relocation on the communications and transportation networks in a non-nuclear environment (13; 25; 26). They also examine the options of total evacuation, standfast (not evacuating but taking hasty shelter), and the relocation of only noncritical workers and all families to rural communities (37). Their study data indicate that small cities (populations of less than 100,000) can be relocated 100 miles into the interior within seven to ten days. The two scenarios which the DCPA believes to be most realistic are: (1) an evacuation initiated in response to a Soviet population relocation as a prelude to a pre-emptive nuclear attack (2; 23), and (2) the commencement of a conventional war in Europe involving an overland invasion of the FRG by Warsaw Pact nations (2; 23). Either of these scenarios would force the activation of the DOD NEO plans.

The DOD plans for NEO were examined by the General Accounting Office (GAO) at the request of Congress during 1978. The subsequent report states:

> Evacuation plans developed by the Department of State and Defense have not been rehearsed to the degree required. . . . Warsaw Pact forces threatening West Germany could strike with very little warning. . . . This means that evacuation may have to be accomplished within a limited time frame, before hostilities start or during actual hostilities. Under these conditions, there would be great competition for roads, railroads, airports, transportation and personnel resources. . . .

> Many dependents could be hurt trying to get to neutral countries or to evacuation points such as airports. . . . Even with sufficient warning, problems in transportation, communication, and other areas would hamper evacuation. These problems would be compounded in a sudden attack or in the event evacuation is delayed for political or other reasons. A delay in the decision to evacuate was a major problem in Saigon in 1974 . . . [10:23].

These charges were refuted by Major General Edgar Chavarrie, Director of Plans and Policy for USEUCOM, when he appeared before the House Armed Services Committee in August of 1979. General Chavarrie said:

> Each of the three evacuation areas in Germany will have full-blown exercises where some of the dependents are put on airplanes and flown around and landed to just follow through with procedures to that extent [19:4].

Research indicates that the last large-scale test of the NEO system occurred in 1962. The most recent test, involving less than 500 prebriefed volunteer dependents from the Army Post at Illesheim, occurred during August of 1978 (29:8). According to the Illesheim Public Affairs Officer, "An exercise of this size may not occur again due to the cost considerations [6:8]." Given the conflict between General Chavarrie's comments and the GAO report, and the absence of any plans for conducting large-scale tests of the existing system by U.S. authorities in the near future, it becomes evident that a reliable method for predicting the time required to implement and complete NEO is necessary. The techniques available to construct such a model are outlined in the following section.

Modeling and Simulation Languages. The basic form of the NEO system is a series of queues, beginning at the evacuees' home base and concluding only when the vehicle on which they are

embarked departs the airspace or territorial waters of the FRG. The three general techniques available for solving queueing problems are analytical, physical analog, and digital simulation. The analytical technique is useful in those areas in which the constraints are known with certainty, and the phenomenon of interest can be defined by the use of complex mathematics. Unfortunately, this is not the case with the NEO system because many of its constraints cannot be known with certainty. The second technique of analog or physical simulations requires extensive setup time; its application is usually limited to representing segments of assembly lines or small factories. In addition, physical analog output is difficult to interpret (3:476). The final method of solution available is digital simulation with a mathematical model manipulated by an electronic computer. Shannon considers this method to be the ". . . most powerful analytical tool available to those responsible for the design and operation of complex processes or systems [27:ix]." Since the NEO system does not readily lend itself to the first two techniques, the authors have elected to use the digital simulation method to model the NEO system.

Digital simulation can deal with large, complex systems while analog models cannot. Furthermore, it allows the researcher to estimate multiple constraints without sacrificing internal validity, which the analytical techniques of linear programming or dynamic programming do not. Computer assisted simulations can be programmed to represent and describe a

dynamic, real-world situation. The situation can then be manipulated to approximate the effect of a single variable on the efficiency or viability of the system. It is relatively easy to implement changes in the model, while it is often difficult or impossible to institute the identical change in the actual system. In addition, it is possible to compress time from a few hours or weeks to a matter of minutes without adversely affecting the validity of the results derived (3:477).

Computers use either general purpose or special purpose languages in their operation. The researchers were fortunate enough to have access to two separate computer systems with both general and special purpose languages. The general purpose languages available to the researchers included FORTRAN, ALGOL, and BASIC (although general purpose languages are very flexible, their use in simulations is discouraged due to their length, complexity, and attendant difficulty in altering the encoded program to reflect changes in structural constraints).

Specialized simulation languages have been developed to make the translation of problems and relationships from the real world to the computer language less tedious than the use of the more flexible general purpose languages. The specialized languages applicable to network or queueing problem analysis include DYNAMO, SIMSCRIPT, GPSS, and Q-GERT and are readily available to the researchers through the CREATE and CYBORG systems. Their relative strengths and weaknesses are discussed below.

DYNAMO is described by Shannon as a language designed to handle continuous flow variables over discrete periods of

time in the queuing model (27:119). The essential variables are state (level) and outputs. These variables are supplemented by a series of auxillary equations which provide the essential feedback controls to the flow within the system. The language is relatively easy to learn, but its emphasis on discrete time rather than discrete objects (i.e. evacuees) renders it inapplicable to the NEO system.

SIMSCRIPT is an event-oriented language. It requires the researcher to identify the conditions which precede an event, thereby stimulating the occurrence of the event; the event is simulated in the continuous time flow of the simulation run. An accurate estimate of the probability distribution of the events is required to verify the accuracy of the model as a predictor of the situation in question. Lacking historical records of any evacuations on the scale which the evacuation of the FRG would entail, and considering the stochastic nature of the variables present throughout the system, this requirement cannot be met. In addition, SIMSCRIPT is relatively difficult to learn, and since it is not specifically tailored for use in queuing problems, it will not be used in this thesis.

GPSS, a language closely related to BOSS, is designed for network analysis. It is reputed to be more flexible than SIMSCRIPT and possesses a variety of statistical capabilities; however, it is difficult to program for queuing applications and requires considerable time to master (27:121).

Q-GERT is a hybrid language developed by Dr. A. A. Pritsker during the late 1960's for specific application in

queuing problems. Although it is queue specific, it was derived from the network language GERT; it retains the flexibility for use in network or PERT applications. Q-GERT uses stochastic process, has extensive statistical capabilities, and is able to assimilate FORTRAN subroutines for augmenting the capabilities of the basic language (22:vii; 27:Ch. 7). Since it is queue specific, flexible, and available, Q-GERT will be used to simulate the NEO system in this research effort.

A more detailed discussion of the NEO system and the interrelationships of its subsystems is presented in the next chapter. Chapter II will also provide specific details on Q-GERT and its application in this research to translate the real world system into our experimental model. A glossary of Q-GERT terms is provided in Appendix A to assist those unfamiliar with this simulation language.

CHAPTER II

SYSTEM DEFINITION AND Q-GERT APPLICATION

Any approach to dealing with complex systems requires a systematic method. In the investigation of the existing NEO system, the steps outlined in Shannon's text as shown in Figure 1 (27) have been followed. Since the problem has been formulated, the next step is to define the system. Various segments of the system descriptions may appear vague or general in nature. This is necessary because certain information about portions of the system is classified. For further information and expansion of the analysis, the reader should consult the following Operation Plans:

1. USAF OPLAN 4102 Classified Secret (39)
2. USCINCEUR OPLAN 4310 Classified Secret (34)
3. 86 TFW OPLAN 4310 Classified Secret (33)

The following section is a detailed description of the NEO system, its ten major subsystems, and their interrelationships. A series of diagrams representing the interrelationships of the various subsystems is included as Appendix B.

The NEO System

A large-scale evacuation of hundreds of thousands of Americans from the FRG hinges primarily on the strategic airlift resources used to bring augmentation forces and supplies

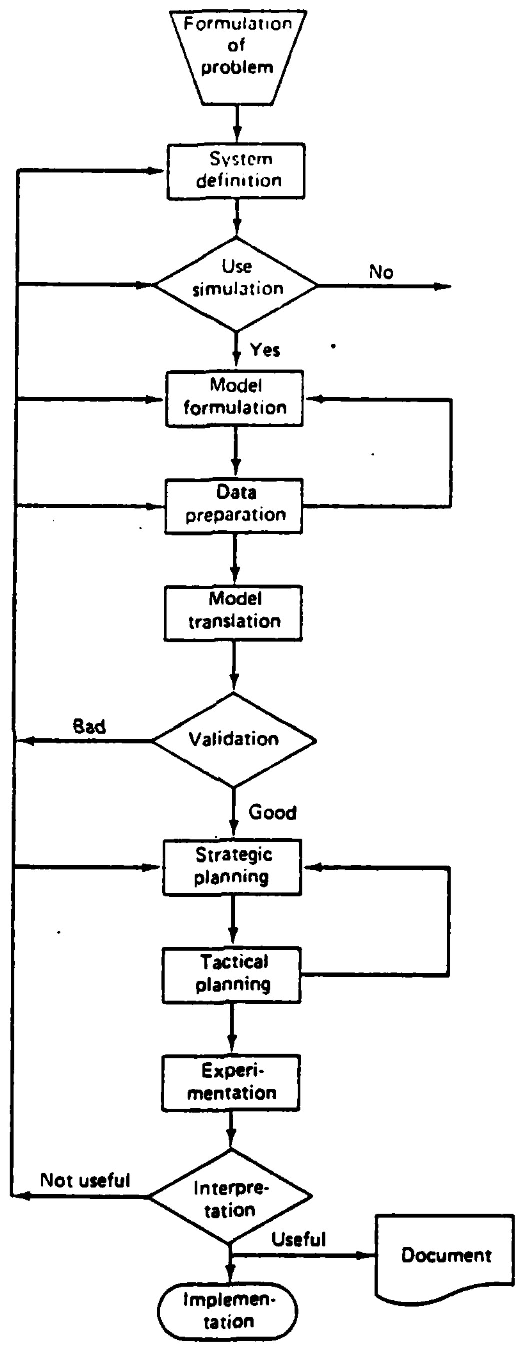


Figure 1 (27:24)

Steps in a Simulation

from the United States to the FRG. Without this strategic airlift force, there is no feasible way to rapidly evacuate the noncombatant populations to the continental U.S. Any limiting factors that affect the deplcvment of NATO-committed forces, via this fleet, to Europe will affect the return of American noncombatants to the U.S. The most crucial component of the overall NEO system is the subsystem of strategic airlift.

The Airlift Subsystem. According to a background paper on U.S. Airlift Forces prepared by the Congressional Budget Office in 1979, the U.S. airlift system consists of two distinct components: organic airlift transports (owned and operated by the U.S. Government) and commercially-owned jet aircraft (36:7). The background paper describes the organic component as being comprised of 77 C-5 Galaxies and 276 C-141 Starlifters, while the commercially-owned transports consist of 375 long-range aircraft (262 passenger planes and 113 cargo planes) (36:8-9). The commercially-owned aircraft comprise the Civil Reserve Air Fleet (CRAF), and are mobilized to augment the organic component during contingencies in three separate stages (36:57). Stage I consists of aircraft committed by contract to a call-up by the Commander of MAC to meet DOD needs, while permitting the civil carriers to continue peace-time operations. Stage II is activated by the Secretary of Defense after conferring with the Secretary of Transportation, and is designed to provide augmentation during an emergency not requiring national mobilization. Stage III is activated after the President or Congress has declared a

national emergency and involves all 375 of the commercially-owned aircraft comprising the CRAF.

The CRAF is made up of both passenger and cargo versions of the Boeing 707 and 747, the McDonnell Douglas DC-8 and DC-10, and the Lockheed L-1011 (36:57). The contracts between the carriers and MAC provide for aircraft, materiel, and crew support sufficient to yield a utilization rate of 10 hours per day per aircraft, with the crew resources being exclusive of those company employees with Reserve or National Guard commitments (36:57). The carriers have letters of agreement with their crews providing that in the event of a strike, the union members will continue operating DOD military passenger or cargo flights as covered by the agreements with MAC (36:57-58). The carriers also agreed to replace any aircraft overseas or in depot maintenance when CRAF is activated so that the total number and types obligated are available on call (36:58). CRAF assets operated extensively under contract during the Vietnam War, though without formal mobilization (36:11). The carriers might be reluctant, however, to commit assets to military operations if it would disrupt routine business too severely, or jeopardize commercial relations with other countries (36:11). The background paper, referenced earlier, points out that CRAF encompasses nearly 80 percent of U.S. civilian long-range cargo transports and 55 percent of long-range, wide-body passenger aircraft (36:11). The paper also mentions that the carriers hesitated to commit assets during the 1973 Israeli airlift because of a potential loss of landing

rights in Arab countries (36:11).

All of these aircraft would not be available at once on the East Coast to participate in a massive airlift to Europe and back. Many are committed to airlift requirements on the other side of the world to support trans-Pacific operations. In addition, CRAF has never been activated in the 27 years since its conception (36:54). It seems logical to assume that the evacuation of all American noncombatants from the FRG would be a national emergency and necessitate the Stage III activation of CRAF. Going one step further, it seems safe to assume that such an emergency would dictate the evacuation of Americans throughout Europe and not just Germany. For the purpose of this research, however, analysis will be limited to the FRG, while recognizing that the assets of the airlift system likely would not be committed in total to an FRG evacuation.

Other major components of the overall system interact with and may limit the airlift subsystem and its effectiveness in returning noncombatants to safety. One of the primary subsystems is that of the airfields to which the strategic fleet must deliver troops and embark evacuees. These have been designated as Evacuation Ports and are the debarkation points for troops and supplies.

The Evacuation Port Subsystem. Long-range strategic aircraft such as the C-5 and C-141, as well as the CRAF assets, require a combination of long runways and large ramp areas with heavy load-bearing characteristics and instrument landing

equipment. The Congressional Budget Office background paper points out that the C-5 and C-141 can operate in less than 25 percent of European airfields (36:16). The Time Phase Force Deployment List (TPFDL) spells out the aircraft type, cargo, passenger composition and destination of airfields. Since this information is classified, it has not been incorporated into this research. The authors have selected destination bases for the Evacuation Port Subsystem by determining if they presently handle wide-body aircraft traffic and their general geographic location in the FRG.

The Evacuation Port Subsystem's interaction with the overall NEO system is constrained or affected by other limiting factors or subsystems besides the type of aircraft available in the Airlift Subsystem. These factors include the availability of fuel reserves for turning around the CRAF assets (assuming the organic transports are refueled aerially), aircraft maintenance capability to keep both components of the Airlift Subsystem flying, and passenger handling equipment to speed up boarding and minimize ground time. It is also affected by the availability or lack of manpower for processing evacuees, the availability of food and water to sustain the evacuees, the availability of facilities to shelter them, and the availability of adequate medical care and sanitary facilities to preclude epidemics. In addition, the security of the base, traffic control, and law enforcement impact on the orderly processing of evacuees at the Evacuation Ports.

The Evacuee Population Subsystem. The potential NEO population plays a major role in the interactions between the various subsystems. Their total number logically affects the amount of time required to evacuate them. The location of the evacuees in relation to the evacuation points and evacuation ports affects not only the time required to notify them and assemble them for placement on departing aircraft, but also the relative strain on surface transportation networks between their locations and the evacuations points and between the evacuation points and evacuation ports. These factors are illustrated in an article about the removal of Americans from Iran in 1978 and 1979, in which the author says:

> Two commercial flights a day were chartered, in addition to the two Pan Am regularly flew from Iran, to handle the additional passengers. The Pan Am flights, leaving from both Teheran and Isfahan, flew 28,400 passengers out of the country from August through February. In support of the American Community in Iran, the Air Force Military Airlift Command flew 34 C-5 and 87 C-141 missions and delivered 5,732 passengers to Athens and Frankfurt during the period of troubles [9:75].

The point being that the numbers were considerably smaller and the people were not as widely dispersed. The 750,000 Americans in the FRG at any given time pose a potentially large burden on existing facilities, supplies and transportation networks. Another major subsystem interacts with the flow of evacuees to the Evacuation Ports. It is logical to assume that the thousands of Americans scattered throughout the FRG will not proceed directly to the Evacuation Ports, but to the nearest U.S. installation. For the purpose of this research, these installations represent the Evacuation Point Subsystem.

The Evacuation Points Subsystem. This subsystem should not be confused with the Evacuation Ports, where the strategic airlift forces are targeted. Rather, this subsystem is comprised of the numerous American military installations scattered throughout the FRG, around which the military dependent population lives, and to which the American tourists or workers would flee. It should be recognized that in a contingency, thousands of tourists and Americans working abroad would attempt to reach American consular offices or make their own way out of the country. For the purposes of this research, it will be assumed that the entire NEO population will be processed through the Evacuation Points and Evacuation Ports.

Many of the same constraints affecting the Evacuation Port Subsystem's interactions with the overall NEO system also affect the Evacuation Point Subsystem's interactions. For instance, manpower for processing evacuees, availability of food and water, and availability of facilities for shelter, medical care, and sanitation requirements. Base security and law enforcement also impact on the Evacuation Points, as well as the distances to the Evacuation Ports, availability of surface transportation networks to accommodate military convoys or privately owned automobiles, and tactical airlift bringing troops to prepositioned equipment. These tactical aircraft could be used to remove evacuees to Evacuation Ports instead of returning empty. In addition, fuel reserves for refueling tactical aircraft and military buses or trucks will affect this subsystem's interactions, as well as the availability

of those buses and trucks. It can be expected that surface transports will be heavily committed to troop and materiel movement. The model will be based upon availability of some assets for transferring the NEO population. The major components affecting the interaction between the Evacuation Points and Ports are the surface transportation networks.

The Road Network Subsystem and Railroad Network Subsystem. The FRG is crisscrossed by a highly developed, modern network of highways and railroads comparable to our superhighways and superior to our own rail system. It is probable that many of these roads and lines of trackage will be closed to all but military traffic, thus blocking evacuees from using their privately owned vehicles or attempting to travel by train. This will affect the numbers able to reach the Evacuation Points for onward processing to the Evacuation Ports. According to the time of year and weather conditions, some of these routes may be closed to all traffic; sabotage and enemy action could also possibly close off various routes, particularly those near the eastern borders of the country. Heavy usage by the native population poses more possible interference in usage for evacuating the NEO population. Still another component of the overall system affects the interrelationships between the destinations, connecting networks, and number of evacuees moved. This subsystem includes the fuels and lubricants necessary to operate the vehicles, and has been designated as the Supplies Subsystem.

The Supplies Subsystem. As previously mentioned, the availability of fuel reserves could have a major impact on the interaction of the various other subsystems. To a lesser extent, the availability of food, water, bedding and medical supplies will affect the movement of the evacuees. Research to date indicates no provisions have been made in the local plans or those at the Major Command Level for feeding and sheltering the expected thousands of evacuees. The 86 TFW NEO Plan requires the noncombatants to carry enough food and water to last each person for three to five days (33). This seems to be a common requirement in all the plans reviewed. On hand stocks of supplies are dedicated to supporting the forces in place and the incoming augmentation forces. Still another subsystem has a potentially more significant impact on the number of evacuees moved than fuel availability. The Political/Military Environment could be such that none of the evacuees are moved.

The Political/Military Environment Subsystem. This subsystem includes agreements between FRG and existing U.S. forces, and international agreements between the FRG, U.S. and other European nations; it also includes the various stages of alert readiness or military conflict during the evacuation operation. Its impact is in the initial decision to implement or not implement NEO. A delay in this decision could result in a loss of lives or a hopeless situation in which there is insufficient time to evacuate the noncombatants without interfering with the mission. This subsystem

affects the decision of whether or not to activate CRAF, thus influencing the time required to move the NEO population.

Sudden escalation in stages of alert or armed conflict will impact on the surface transportation networks, closing some and overloading others. International agreements may close borders to surface crossings or overflight priviledges, thus affecting the interrelationships between the Evacuee Population, Airlift, Road, Railroad, and Evacuation Port Subsystems. For the purposes of this research, it will be assumed that the FRG will not hinder the operation through political means or unnecessarily restrict surface transportation networks or communication networks. Where the political or military situation might not seriously impair the operation, the last two major components of the NEO system could still delay or block the overall operation.

The Weather Subsystem and Communications Network Subsystem. The weather conditions throughout Europe, over the North Atlantic, and in the U.S. affect the generation and safe passage of the aircraft on both sides of the Atlantic, possibly increasing the time required to evacuate the population. Bad weather can seriously disrupt the ground movement of the evacuees and add to the shelter problem faced by the installation commanders at the Evacuation Points and Ports. It can also disrupt communications and coordination between the various installations and inbound aircraft. Like the weather subsystem, the Communications Network Subsystem interacts either directly or indirectly with all other major components of the

NEO System. Without communications, there could be no coordinated evacuation effort. There are a limited number of radio frequencies available in the FRG, and they are tightly controlled for use by the various NATO forces operating throughout the country. As such, there are no channels assigned strictly for command and control of the overall operation, and the possibility exist for significant distortion or delay in coordination between the various Evacuation Points and Ports. For the purpose of this research, an assumption will be made that there is no interference in either trans-Atlantic or intra-theater communications.

In summary, there are at least ten major subsystems interacting with each other and within the overall system. As mentioned previously, these interrelationships are depicted in the figures in Appendix B. The authors have elected to purposely omit one additional subsystem which is comprised of the harbors and ocean-going vessels available to the U.S. Sealift Command. The rationale for this omission being that in the event of a heightening of tension, the ships would be put to sea immediately to prevent their being destroyed in a surprise attack, and an over-sea evacuation would not contribute significantly to a reduction in the NEO population. The overall NEO system is quite complex and assumptions are required to simplify it for modeling purposes. These will be discussed in the chapter on methodology. The next section deals with the application of Q-GERT modeling techniques to the problem discussed and system outlined.

Q-GERT Techniques

Q-GERT is used to model projects consisting of sets of activities. It augments generalized Program Evaluation and Review Technique (PERT) concepts by adding queuing and decision capabilities, thus satisfying the need for a network approach to the modeling of systems involving procedural and random elements (22). Q-GERT allows the depiction of the interaction between various elements and activities as either deterministic or probabilistic. The modeler is required to establish parameters for each activity being modeled, with those parameters representing either a constant service time or the characteristics of different probability distributions. For example, a road connecting an Evacuation Point to an Evacuation Port may have a constant travel time assigned because it has historically never been closed by weather conditions or is located to have a minimum risk of closure by sabotage or enemy action. On the other hand, travel times may be subject to wide variances along some routes because of weather conditions, availability of buses or trucks, or other probabilistic factors. Depending on the particular probability distribution assumed, the modeler specifies a mean service time and standard deviation or a mode service time with an accompanying optimistic and pessimistic service time (22).

Certain variables in the NEO system are deterministic in nature, or are assumed to be for the purpose of this research. Among these are the number and locations of the

evacuees, the number and types of aircraft, the passenger capacity of the various aircraft, the number of buses or trucks available at specific locations, the number of facilities available for sheltering evacuees, and the availability of various supplies and fuels. Specific assumptions about the deterministic variables in the system will be included in the discussion on the model description. This discussion will also include the rationale behind assignment of probability distributions and associated parameter sets for the various stochastic variables involved in the system model. In the actual system, the evacuees' travel times to the Evacuation Points and subsequent onward movement to the Evacuation Ports are functions of the mode of travel selected, route accessibility, travel restrictions associated with various stages of alert or armed conflict, and their processing times at intermediate points.

Q-GERT permits the stacking up of variables awaiting service into queues when the service activities are being completely utilized. It also allows the modeler the option of establishing queue selection rules, server selection rules, or both to determine which variables or transactions will be serviced when a service activity becomes available. These selection options permit us to service those transactions with the longest waiting time or shortest waiting time from single or multiple queues feeding the service activities. The next chapter will describe in more detail how specific selection rules were applied in transforming the system description into

the mathematical model. The chapter on methodology will provide additional details concerning the establishment of queues in the NEO system and the eventual matching up of transactions (evacuees) and other transactions (aircraft).

Q-GERT has an embedded analysis program that provides statistical information for the various queues and service activities. These statistics include the average number of transactions (evacuees) in the queues, their average waiting times, standard deviations of the averages, minimum and maximum numbers of transactions in the queue for one simulation run, and the maximum number of transactions in the queue during one run of a series of simulation runs. Q-GERT permits the modeler to choose either a single run or multiple runs, based either on time constraints or a specified number of transactions reaching a destination at the end of the model network (this destination is called a sink node). Each time a transaction reaches the destination, it is considered to have released the node, thus signifying completion of its activity. As mentioned in the introduction, a glossary of Q-GERT terms is included as Appendix A to assist those who are unfamiliar with this language.

Other statistics provided by the Q-GERT analysis program include the average server utilization, the longest consecutive period of time that a single server is idle or busy, and for multiple parallel servers, the average number of busy servers. Q-GERT is very flexible in permitting the modeler to use either a single server or multiple servers to represent a

particular service activity. For example, the ground transportation networks between Evacuation Points and Ports could be depicted as a single main artery with possible "bottleneck" effects or a set of parallel routes representing secondary roads in addition to primary autobahns or rail routes. Multiple servers can be used to indicate processing activities at intermediate points in the NEO system or boarding ramps to aircraft at the ports. Statistics are also provided for sink nodes or end destinations in the model network. The sink nodes in our model will signify departure from the FRG or possible capture by advancing enemy forces. The modeler is also afforded the option of inserting special nodes, called statistics nodes, in the network design for which the analysis program will compute statistics. Primary interest will be in the release of a sink node indicating the evacuation of all the NEO population or a predetermined fraction of that population. The other statistics are useful for analyzing the potential problem areas in the system or determining where to reduce activities and re-allocate surplus assets. Results of the simulation runs for the NEO system will be presented in Chapter IV, where a sensitivity analysis will be performed to evaluate the options presented in Chapter III.

This chapter has presented a fairly detailed description of the ten major components of the NEO system and a discussion of Q-GERT techniques and their application to the NEO system. The next chapter will elaborate on the transformation of that system into a workable model via Q-GERT. Assumptions required

for system simplification will be included, as well as data sources to delineate variables representing the various sub-systems of the overall NEO system. This model description will then be followed by a discussion of our experimental plan of attack for validating the model and conducting sensitivity tests of various subsystem factors.

CHAPTER III

METHODOLOGY

Introduction

As previously mentioned, certain assumptions are required in order to deal with a complex system for transformation into a model. This is necessary to reduce the system's complexity to a level which can be defined, categorized, and manipulated in a digital simulation. Burdick has defined digital simulation as ". . . a means to derive sample data and statistical estimates from a model. As such it is distinguishable from the analytic procedures which seek to optimize some criterion [3:476]." The objective of these assumptions then is not to optimize one or more variables of the subsystems, but to enable the collection of statistical data for making recommendations concerning various aspects of the overall system.

Overview

This chapter contains a discussion of the assumptions made in dealing with the complexity of the NEO system. Causal loop diagrams are used to illustrate the initial concept of the system prior to transforming it into a Q-GERT network model. This is followed by a detailed description of two Evacuation Port network models representing a military and

civilian airfield respectively. The next section contains a discussion of the methods of analysis used in this research, and a description of the data elements generated by the computer simulation. The chapter concludes with a summary discussion of model manipulations and limitations of the analysis methods chosen for this research.

Assumptions Concerning the Political/Military Environment

The first major assumptions concern the Political/Military Environment Subsystem. For modeling purposes, it is presumed that the government of the FRG will in no way interfere with the evacuation of the entire American noncombatant population. On the contrary, this model assumes that full cooperation will occur, with the FRG augmenting ground transportation assets with either contracted commercial buses and trucks, trains, or military vehicles. In addition, it will be assumed that agreements with other European countries will permit the strategic airlift forces to traverse their respective airspace without interference. Most importantly, it will be assumed that the air corridors to Berlin will remain open until those noncombatants are removed. It will also be assumed that there will be no interference with the existing communications networks during the duration of the evacuation operation. The primary military-related assumption is that the contingency precipitating the evacuation will escalate to a conventional war between NATO and the Warsaw Pact nations in the FRG. This follows the scenario

outlined in The Nuclear Crisis of 1979, in which the conflict does not escalate to the use of nuclear, biological or chemical weapons until after the arrival and deployment of all of the augmentation forces from the U.S. (2). It will be assumed that enemy forces advancing into the FRG will cut surface transportation routes and overrun various Evacuation Points and Ports, taking prisoner any of the noncombatants not yet evacuated to safety. The approximate number of hours until the respective fields are overrun will be inserted in the model to account for diverted groups of evacuees and captured noncombatants. These times are based on the scenario described above. Certain assumptions about those noncombatants are also required for construction of the model.

Assumptions Concerning the NEO Population

The exact counts and locations of potential evacuees are available through classified State Department reports (40) and will not be included in this study. The population of 750,000 is considered to be distributed throughout the FRG, and targeted specifically against six strategic airfields designated as Evacuation Ports. Furthermore, all evacuees will be considered to process through the Evacuation Points and Ports, rather than escaping on their own across the borders by auto or rail, or by flying on regularly scheduled commercial flights. The model will allow for the simulation of those evacuees who elude or are overlooked by the official evacuation system and make their own way to the Evacuation

Ports. The model will be configured to reflect the first noncombatants being evacuated as those living on or near to the strategic airfields, thus making room to shelter the evacuees coming in from the outlying areas. It is presumed that their proximity to the airfields would minimize the time required to notify and assemble them for loading on board in-theater assets for the trip to the U.S. to pick up reinforcements.

Assumptions Concerning the Evacuation Point and Ports

Having reduced (for the purpose of this model) the uncertainty associated with the Political/Military Environment and the NEO population, it is necessary to reduce the complexity of their interactions with the other components. Two of the primary components of concern are the subsystems of Evacuation Points and Evacuation Ports. A confounding factor of complexity in the overall system is whether or not there are sufficient supplies available to support the evacuees at the Evacuation Points and Ports. In order to reduce that complexity, the model considers food and water to be no problem, with the evacuees either subsisting on the rations they carry, or going without food until they reach safety. This assumption is valid for the military dependents because local plans emphasize their being self-sufficient (33). Many of the evacuees involved in the operation in Iran remarked on the non-availability of food during their evacuation (9). It would be logical to presume that passengers boarding

evacuation aircraft would be asked to leave as much unnecessary weight behind as possible, to make room for additional passengers (especially on cargo aircraft). It is presumed that this would include food items, which could be collected at a processing point in the air terminal and used to sustain evacuees just joining the queues or those who did not bring along food (i.e. tourists and people away from home when the operation was initiated).

Eighteen major U.S. installations constitute the Evacuation Points where the people are assembled into groups for onward movement to the Evacuation Ports via convoys escorted by military personnel. This has been defined to deal with the complexity of many installations feeding into one or more Evacuation Ports, by designing each Port to be fed by only three Evacuation Points. A separate medical evacuation system exists in which every effort is made to keep families with the patient being moved. This system will not be addressed in the model because it is not comprised of the strategic airlift assets dedicated to the reinforcement of the FRG.

The medical and sanitation facilities at each Evacuation Point and Port will not affect the number of evacuees processed through each respective installation. Food, water, medical care and sanitation facilities place an upper limit on the number who can be crowded together at one time without the outbreak of epidemics or the needless discomfort of hunger and thirst. Data was not available to determine those upper limits, so the supplies and facilities are assumed to be

sufficient to accommodate the numbers specified for this model. This also applies to ground fuels, which are considered sufficient to service all convoy vehicles; however, fuel stocks could be considered to limit the number of vehicles operated, therefore the sensitivity analysis of vehicle parameters can encompass the concept of fuel availability.

In the original approach to modeling this system, it has been assumed that the following airfields would be the primary Evacuation Ports because they presently handle C-5 or wide-body traffic. The numbers in parentheses represent the total number of evacuees to be processed by that airfield in this model of the system. The airfields and rationale are:

1) Rhein-Main AB (208,400 evacuees): largest MAC operation in the FRG; handles C-5, C-141, and commercial aircraft; also centrally located with large concentrations of tourists and military dependents.

2) Ramstein AB (184,600 evacuees): large MAC operation in southwestern part of FRG; handles C-5 and C-141 aircraft; also large concentration of military dependents.

3) Spangdahlem AB (75,000 evacuees): large runway, fighter base in far western area of FRG; capable of handling C-5, C-141 and commercial wide-body aircraft.

4) Munich (122,000 evacuees): largest commercial airport in southeastern part of FRG; handles wide-body aircraft; large concentrations of tourists and near many military installations with dependents.

5) Stuttgart (100,000 evacuees): large commercial

airfield midway between Munich and Rhein-Main; handles wide-body aircraft; large concentrations of military dependents in vicinity.

6) Hannover (60,000 evacuees): large airport in northeastern part of FRG; handles wide-body aircraft; presumed to handle all northern evacuees.

Only Rhein-Main and Munich are modeled in this research effort for two reasons; first, because they would handle approximately 40 percent of the NEO population and second, because they represent logical end-destinations for augmentation forces and supplies (especially outsized cargo like tanks and helicopters). The next set of assumptions addresses the Airlift Subsystem and its associated components.

Assumptions Concerning the Airlift Subsystem

The first major assumption required for dealing with the complexity of this subsystem concerns the number and type of aircraft in place and to be used throughout the operation. The exact numbers are available in classified plans and will not be used in this report (39). Airlift commitments will still exist in other theaters of operation, and various aircraft will be unavailable because of depot maintenance requirements. It is illogical to assume that all strategic airlift capacity will be targeted to the FRG in light of current planning for one-and-one-half wars. This refers to the concept of supporting a force engaged in a limited conflict as well as a full-scale war. In addition, airlift is

going to be required to other European countries in NATO, but ideally on a smaller scale than the requirement for the FRG. There are few who would argue that the U.S. is not committed to a large-scale airlift to the FRG; this is proven each year during the massive Reforger (Return of Forces to Germany) exercises conducted by the NATO allies. The question then is, how much airlift capacity will go to the FRG versus world-wide and inter-European theater? In order to model the range of possible aircraft availabilities, the following upper and lower limits were established.

The initial number of U.S. airlift assets assumed to be in place in the FRG at the beginning of the operation will be a minimum of 31 C-5s (40 percent of the total fleet) and 110 wide-body aircraft (C-141s and CRAF assets). Even though CRAF assets range from Boeing 707s and DC-8s to Boeing 747s, an attempt was made at smoothing this variance by designating them as C-141 equivalents. An upper limit of aircraft availability has been set at 57 C-5s, 124 C-141s, and 83 CRAF assets. This assumption permits continued domestic aerial operations, allows for other MAC airlift commitments, and reflects probable aircraft assignment to the support of other U.S. missions in Europe. Fewer assets will be available in the actual system due to increased maintenance requirements associated with increased aircraft utilization rates (average daily flying hours by type aircraft for the total number of that type).

It is assumed that sufficient crews are available to

sustain fleet utilization rates of 12.5 hours per day for C-5s and C-141s, and 10 hours per day for the CRAF assets (31). Therefore, this parameter of the system is not directly modeled in this research. However, aircrew availability could be reflected in the aircraft availability parameter since airplanes cannot fly without crews, and a shortage of crews, therefore, means a shortage of aircraft.

In addition, it is assumed that the C-5s will carry 720 passengers, while the C-141s and CRAF assets only carry 360 passengers each on the return trip to the U.S. (36). This permits construction of a simpler model in which a single transaction can represent either a C-5 load or two C-141 equivalent loads. In reality, the cargo aircraft are not configured to carry those numbers of passengers, but in an emergency situation could easily accommodate them (uncomfortably perhaps).

It is further assumed that no strategic airlift assets are captured by enemy forces overrunning the eastern airfields or lost to enemy fighters during the duration of the operation. As fields are overrun, the assets are presumed to be rerouted to rear area fields. This assumption is based on an adequate communications network keeping the mission directors advised of operating airfields still in our possession at any given time.

The final set of assumptions deal with the surface transportation networks and the weather.

Assumptions Concerning the Weather, Road Network, and Rail Network Subsystems

These assumptions are all that remain before constructing the model of the system. As mentioned previously, it has been assumed that there are three primary Evacuation Points associated with each Evacuation Port. The road networks connecting Points and Ports will be the primary means for moving the evacuees. They will be assumed, for the purpose of this research, to be moved in convoys of twelve, 60-passenger buses, forty-eight 2-1/2 ton trucks, or a mixture of vehicles with equal capacities over the road networks. This assumption permits continuity in the model by establishing this relationship of people to vehicles as a means of keeping transactions at one size (720 people).

The following parameters constrain the surface movement of evacuees. Convoys are considered to make a round trip in five to eight hours during the summer, and eight to sixteen hours during the winter. Furthermore, it is assumed that convoy movements will operate 24 hours a day during the summer, and a maximum of 16 hours a day during the winter. These assumptions are based in part on guidelines provided in DOD regulations governing the operation of motor convoys and an interview with the Camp Logistics Chief at Camp Elmore, near Norfolk, Virginia (18). Any convoy of mixed vehicles can only go as fast as its slowest member; that speed is 45 m.p.h., which is specified by regulation as the top speed for all tactical vehicles (including 2-1/2 ton trucks). In order to

simulate the worst possible conditions, travel is permitted only 16 hours per day in the winter because icing conditions are at their worst at night, and round trip travel times were doubled because convoy speeds are cut in half during inclement weather. Both sets of travel parameters are uniformly distributed to account for various types of delays that may be encountered on different trips. Stragglers using POVs will be assumed to make a one-way trip in eight to sixteen hours, regardless of the season, in order to simulate delays by authorities, travel on secondary roads, and getting lost.

Logic dictates that the rail network be primarily used for transferring large numbers of evacuees from overcrowded Evacuation Ports to other Ports with little or no backlogs. It is assumed this would be most likely to occur if aircraft movement to a specific field were interrupted by weather conditions or changes in the strategic airlift mission. It is recognized that rail traffic in a contingency will mostly consist of troop and equipment movements, but it is assumed that coordination between U.S. and German military forces would permit "special evacuation" trains to be used for large-scale transfer of noncombatants. In any event, this model will not represent any movement of evacuees by rail.

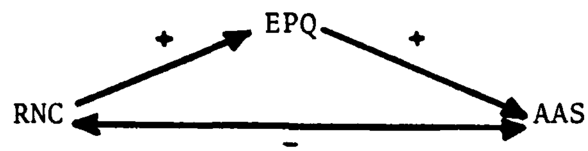
Probability distributions for weather conditions for each region of the FRG were not available for incorporation into this model. Therefore, the stochastic qualities of weather are not included in the system parameters. Instead, summer is considered to represent the optimum conditions for conducting

a large-scale evacuation, while winter is considered to represent the most pessimistic. The primary impact of this assumption is presented in the model as increased transit times for road travel, with no affect portrayed for increased flying time, the rerouting of missions, or blocked surface routes.

This concludes the major assumptions used in translating the overall system into this model. The next section contains a detailed description of the model. Any additional assumptions or constraints caused by the computer system's limits have been incorporated in the model description.

Description of the Model

Before describing the working model, the transformation process resulting in that model requires some discussion. The overall system could be represented by a collection of causal loops depicting the interactions between subsystems or components of the overall system. The causal loops are formed by causal pairs sharing a common variable and joined by a feedback loop which initiates change in one or all of the variables as a result of the union. Figure 2 demonstrates this concept for the relationships between the number of evacuees waiting at an Evacuation Port, the Airlift Subsystem, and the Road Network to the Point. If a feedback-initiated change is in the same direction, it is signified by a "+", if in the opposite direction or there is no correlation in change, by a "-". As aircraft seats become available, the number of evacuees waiting in the queue becomes smaller, thus



AAS: Available Aircraft Seats
EPQ: Evacuation Port Queue
RNC: Road Network Capacity

Figure 2

Example of Causal Loop

the relationship is indicated by a "+". Conversely, the fewer seats available, the longer the queue grows. As more people are carried on the road network, more people join the queue, and this relationship is indicated by a "+". The number of seats available has no correlation with the road capacity and vice versa, so their relationship is indicated by a "-". Of course, many other factors interact with these components, such as weather, communications, and supplies, but the example serves to illustrate the following points made by Goodman (11). These types of figures provide the researcher with a graphic description of the variables under consideration, and by providing a representation of the model that can be manipulated, allow him to examine his assumptions prior to attempting to encode the simulation digital program (11:5). Bearing this concept in mind, Figure 3 represents an initial concept of the overall system, aimed at determining the time required to evacuate the FRG. The components interacting with the dependent

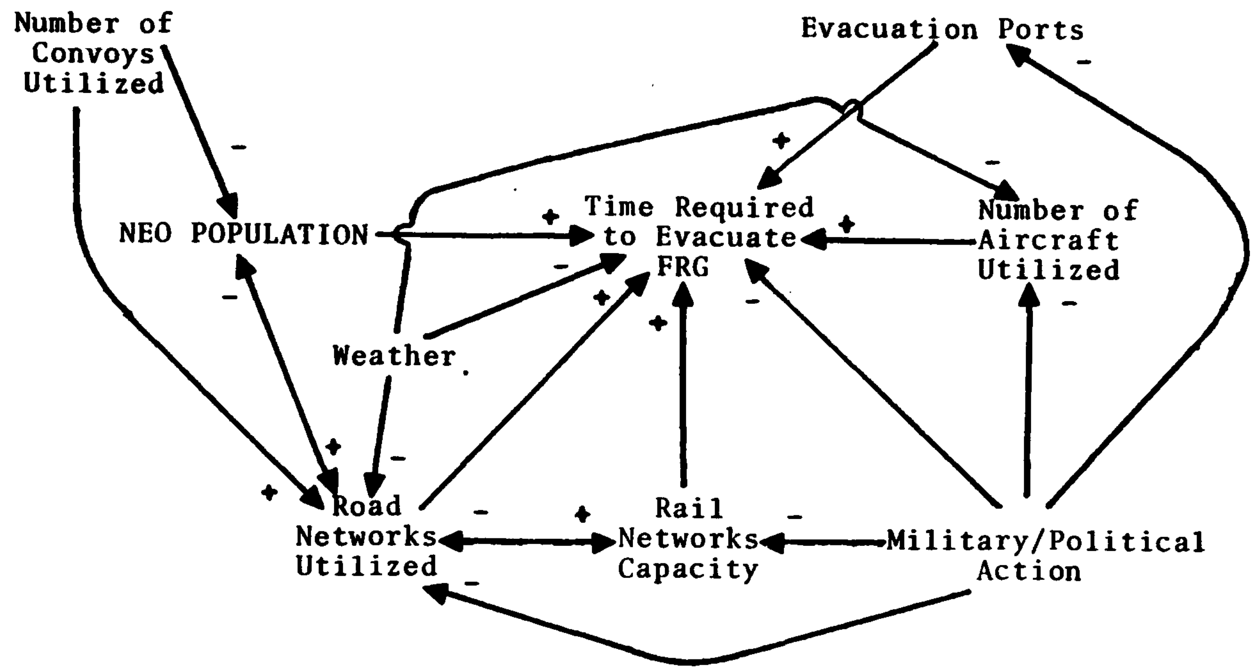


Figure 3

NEO System Relationships

variable of time are joined by feedback loops and symbols indicating the direction of change. The time required to evacuate is increased by an increase in the NEO population, bad weather, a decrease in road capacity or number of convoys, a decrease in the number of available aircraft or airfields, or a decision to delay the evacuation. Conversely, the time required to complete the evacuation is decreased by the reduction in the NEO population, good weather, an increase in available convoys, aircraft or airfields, or a delay in the escalation of military activity by the enemy. The system remains complex, but this concept allows us to deal with that complexity by reducing it to something we can handle. In going from the general to the specific, the next section deals with that portion of the system actually modeled.

The Two Evacuation Ports Modeled. As mentioned previously in the section on assumptions, this simulation effort encompasses only two of the six Evacuation Ports described. The other four can be simulated as parallel operations by merely shifting appropriate numbers of resources and evacuees to each respective airfield. The first Evacuation Port modeled is that representing Rhein-Main AB, near Frankfurt.

The causal loop diagram of the overall system is converted into a network model for each port primarily by assigning queue nodes and servers to the various components represented in the diagram. For instance, the NEO population is translated into an initial number of transactions present in the Evacuation Point queue nodes at time zero, and the

subsequent release of a transaction at periodic intervals by the source node. The service times required to move the transactions through the network model are accumulated and result in the dependent variable of interest, the time required to evacuate the total number of evacuees designated in the model. Of course, that is a simplified description of the transformation process from a conceptual diagram into a simulation network, and does not include all of the factors required to represent interactions. For example, the interaction of the airlift subsystem with the NEO population, and the Evacuation Port is represented by a queue node where transactions representing people are held in an area waiting to board aircraft represented by servers with a probability distribution of round trip flight times to the U.S. The conceptual diagram is thus transformed into an actual model by using the assumptions previously discussed along with their associated parameters and the tools of Q-GERT.

Figure 4 is the Q-GERT schematic of the model. A glossary of Q-GERT terms is available in Appendix A to assist those unfamiliar with this language. The second Port modeled is Munich; its description immediately follows that of Rhein-Main.

<u>The Rhein-Main Model</u>. In accordance with the previously discussed assumptions, Rhein-Main is designated to move 208,400 evacuees converging onto three Evacuation Points before arriving at Rhein-Main, and approximately 9,000 evacuees arriving at Rhein-Main via airlift from Berlin. The discussion

refers to the activities illustrated by Figure 4. The surface-borne evacuees are generated at source node 130 as a new group of evacuees every 1.9 hours for the first 96 hours of simulation. This parameter represents the time lag associated with the psychological indecision of tourists, local traffic delays, and communication failures in notifying evacuees where to assemble. An additional assumption of the model is that anyone wishing to evacuate will be moving by the end of four days and any remaining Americans would have either fled by other means or elected to stand fast. The Berlin evacuees enter the model at regular node 132 as a normal distribution of arrivals over a 96-hour period. Appendix C contains details of how this distribution and time limit were determined.

Source node 130 has conditional take-all branching which results in duplicate transactions flowing to regular nodes 90 and 132. The activity from source node 130 to node 90 represents surface evacuees' travel times as a normal distribution of between three and seven hours due to their use of different modes of travel and distances from the Evacuation Point. Node 90 then translates this into six simultaneous arrivals at the three Evacuation Points feeding into Rhein-Main and depicted as queue nodes 230, 240, and 250. Each transaction flowing from node 90 through the network to sink nodes 4 and 1 represents a group of 720 evacuees (the equivalent of one C-5 load). Points are assumed to be within two "peace-time" driving hours (one-way) of Rhein-Main by autobahn. For convenience and to reduce variety, each of these queue

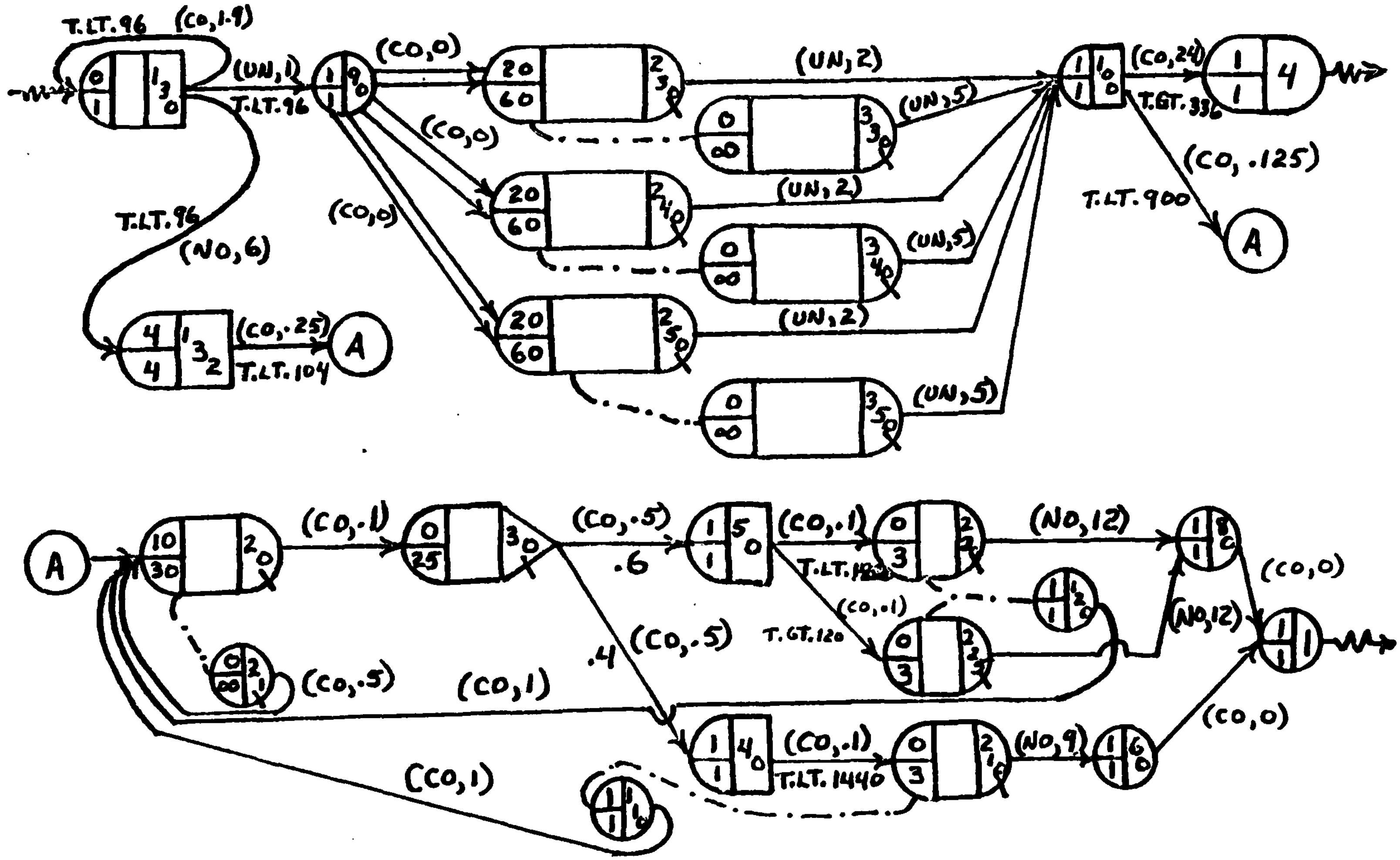


Figure 4

Rhein-Main Network Model

capacities has been set at 43,200 evacuees (the equivalent of 60 C-5 loads), with 14,400 evacuees (the equivalent of 20 C-5 loads) already in queue when the simulation begins. These represent the military dependents and U.S. citizens already on or nearby the Evacuation Points. Provision has been made to route balkers to queue nodes 330, 340, and 350 to represent independent groups of evacuees making their own ways to the Evacuation Port. Their subsequent travel times to node 100 are uniformly distributed between eight and sixteen hours to represent the use of backroads, getting lost, or being delayed by authorities directing military traffic.

The activities from queue nodes 230, 240, and 250 (Evacuation Points) to node 100 represent the convoys specified in the assumptions as either twelve, 60-passenger buses or forty-eight trucks, carrying 720 evacuees to the Evacuation Port. The convoy's round trip travel times to the Port and back are uniformly distributed from five to eight hours for summer travel, and from eight to sixteen hours for winter travel. Upon reaching node 100, the convoys are, therefore, considered to be back at their respective queue nodes to begin another trip to Rhein-Main. Node 100 has conditional take-all branching to allow the option of rerouting incoming evacuees to alternate Evacuation Ports if this one has been overrun by enemy forces. The condition being tested is whether simulation clock time is greater than 336 hours, which represents the estimated overrun time for Rhein-Main derived from scenarios in <u>The Nuclear Crisis of 1979</u> (2). If clock time

is less than 336, evacuees continue to queue node 20, and if clock time is greater than 336, they are rerouted to sink node 4, which represents assignment to another Evacuation Port for airlift. This feature, of creating duplicate transactions after clock time equals 336, permits data collection for the number of evacuees (designated to depart via this Port) who are still enroute when it is overrun, while simultaneously allowing the network to function in a "normal" manner as if it were not overrun. This results in a total time to evacuate designated noncombatants through the respective Evacuation Ports.

Queue node 20 represents an on-base holding area for shelting 21,600 evacuees (30 C-5 loads) in excess of the 18,000 (25 C-5 loads) temporarily held adjacent to the passenger terminal in queue node 30. Eighteen thousand passengers can be kept available to immediately board incoming aircraft without impairing mission operations (or being constrained by limited availability of food, water, shelter, or sanitary facilities). This assumption is offset by the 21,600 assumed to be sheltered in base housing, schools, chapels, gyms, and theaters on base, and the knowledge that, in reality, only a few thousand would be directly on or near the flight line at any time while the balance of the 39,600 would be in the temporary shelters described or enroute to the flight line area at any given time. If both queue nodes 30 and 20 are full, then balking will occur in front of queue node 20, with the evacuees being branched to queue node 21, representing

off-base billeting approximately 30 minutes from the base. This feature of the model permits the simulation of a policy for handling an overflow of evacuees that exceeds the support capacity of the Evacuation Ports. One of the balked groups is reintroduced to the main on-base holding area (queue node 20) every half hour, to simulate transfer of evacuees from an off-base holding area. If an aircraft has not come in and a group from queue node 30 not departed, this unfortunate group will then be rerouted to queue node 21.

When a group has reached queue node 30, aircraft designation takes place via a probablistic branching which routes 40 percent of the evacuees to a queue for C-5 aircraft and 60 percent to a queue waiting to board either C-141s or CRAF assets only. Nodes 40 and 50 represent branching points where a different version of the model would have conditional take-all branching to route duplicate transactions to another sink node (not shown) that would represent evacuees captured by advancing enemy forces. The condition being tested would be simulation clock time greater than a specific overrun time for the entire country. This feature is similar to the one previously described that permitted "what if" data collection, but also permitted "normal" operation. Queue nodes 210 and 220 represent immediately available holding areas out on the aircraft parking ramp where three groups of 720 evacuees can quickly board aircraft as troops and cargo are being off-loaded. The authors assume engine shut-down and off-loading of troops and cargo through rear hatchs while evacuees board through the

forward access points. Because the wide-body aircraft carry half the passenger load designated for the C-5 in this model, the number of servers between queue nodes 220 or 225 and regular node 80 are divided by two, thus a transaction from node 80 to sink node 1 represents the same group size as a transaction between node 60 and sink node 1 (720 evacuees) and two aircraft in service. Transactions are routed through queue node 225 rather than 200 whenever clock time exceeds 120 hours. This represents an increase in available aircraft because the southern and eastern airfields of Munich, Hannover, and Stuttgart are presumed overrun or closed by enemy air action by the end of five days in The Nuclear Crisis of 1979 (2). Queue node 225 has more servers associated with it than 220, thus accounting for the increase in aircraft assets. Activities from these queue nodes to regular nodes 60 and 80 represent refueling and offloading/onloading time requirements in addition to round trip flight times to the U.S. and offloading/onloading times at the other end. It is assumed that there will be no ground refueling operations at the Evacuation Port, with either aerial refueling being done on either or both Altantic crossings or non-midair, refueling capable aircraft landing at intermediate fields in Great Britain, Iceland, or Greenland. The distributions for these times are based, in part, on the block-in speeds for the various aircraft and an approximate distance of 3,540 nautical miles from Dover AFB to Rhein-Main. These times are normally distributed from 28 to 48 hours, with a mean of 31 hours for C-5s, and

28 to 48 hours, with a mean of 34 hours, for C-141s and CRAF wide-body aircraft. MAC planning documents contain ideal round-trip flying times for a C-5 as low as 20.9 hours for a block-in speed of 428 mph, and 23 hours for a C-141 with a block-in speed of 407 mph and no ground time. The planning guides also contain sufficient time factors to allow for intermediate refueling, minor maintenance, and unexpected delays during onloading/offloading and crew change-outs (31). The time factors bring the round trip times up to the parameters described for this model, but they can be varied as another modeler desires. From regular nodes 60 and 80, the evacuees disappear into sink node 1, which represents the U.S. No attempt has been made to simulate the onward movement of the evacuees once they reach the U.S.; they are considered safe at this point.

Balking of transactions from queue nodes 210 and 220 to 110 and 120 respectively takes place. This feature has been incorporated to simulate a confusion factor in the evacuation operation. The balked groups are returned after an hour to queue node 20, thus delaying them from boarding an aircraft for quite some time, and approximating a situation that has often occurred during large-scale operation in the past. It is presumed that Murphy's Law is applicable and that no matter how well coordinated an operation may be, someone will be in the wrong place at any given time.

That traces the movement of surface arrivals at Rhein-Main through the network. Now to discuss the aerial arrivals

from Berlin. Each transaction passed from source node 130 to regular node 132 represents a group of 180 evacuees. Node 132 requires four releases before it releases a transaction, representing 720 evacuees, to queue node 20. Once the transaction reaches queue node 20, or is balked to queue node 21, it is processed the same way as the "surface" groups described previously. The model is constrained to simulate 900 hours of activity, which exceeds the estimated overrun time by more than two weeks. This is done to ensure collection of outlying data points that could possibly vary significantly from a population mean of evacuation times. The next section describes the model network for Munich.

The Munich Model. The discussion concerning this model refers to the network illustrated in Figure 5. The Q-GERT network for Munich was developed along the same conceptual lines described in translating the causal loop diagram into the network model for Rhein-Main. Queue nodes and servers were assigned to represent the various interacting components. The most obvious differences between the two network models are the omission of a branch for simulating incoming evacuees from Berlin and a branch for C-5 aircraft departures to sink node 1. This model has been constructed under the assumption that the C-5 aircraft will only be targeted against the three military airfields because of cargo handling requirements. Another major difference between these two networks is the number of evacuees processed. Rhein-Main has almost 100,000 more to handle.

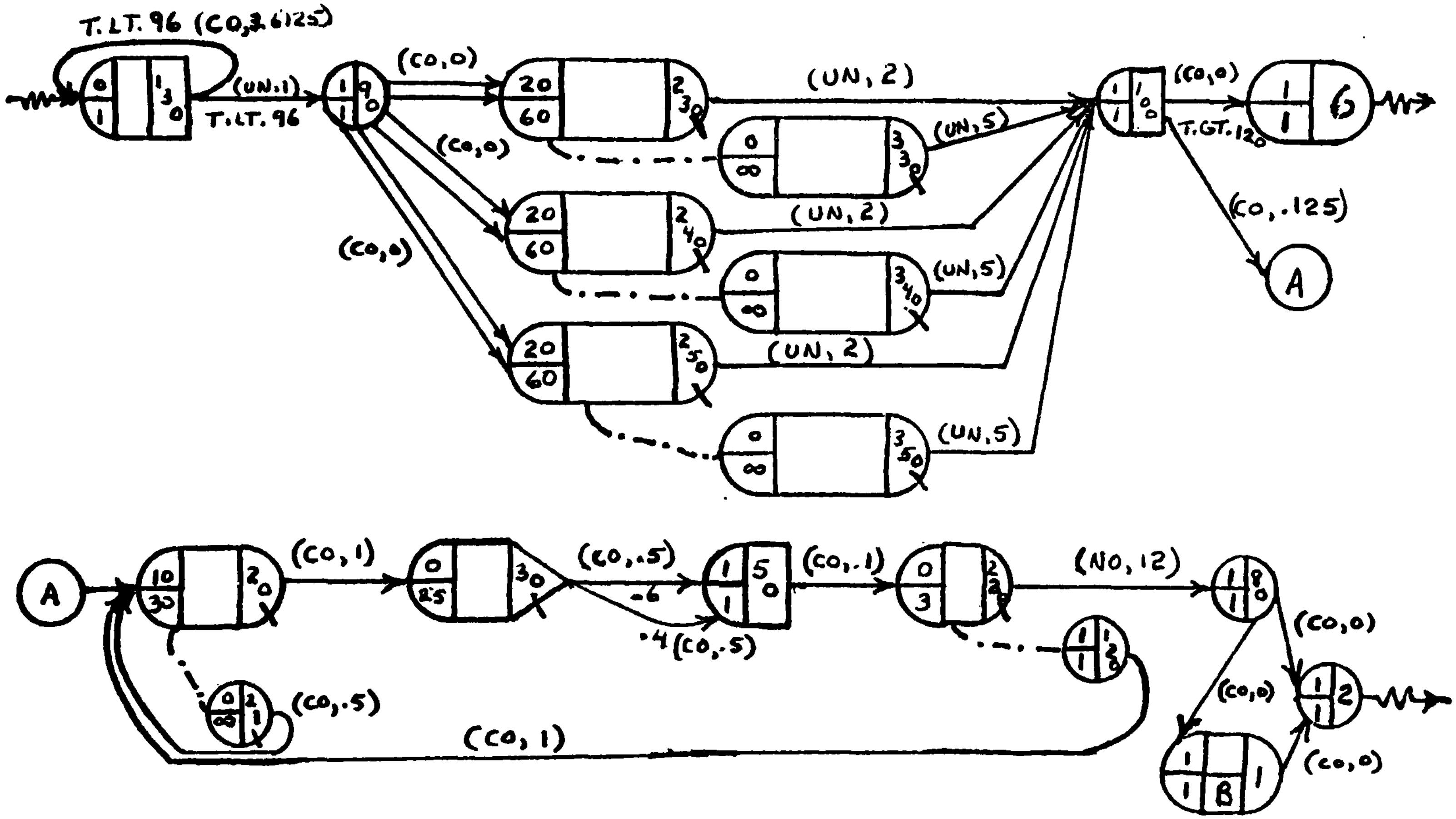


Figure 5

Munich Network Model

Perhaps less obvious is the overrun time condition test between node 100 and sink node 6 in this model. Whereas the Rhein-Main model uses an overrun time of 336 hours, the model for Munich uses an overrun time of 120 hours. As in the previous model, however, the conditional take-all branching emanating from node 100 permits duplicate transactions into queue node 20, to simulate normal operations and subsequent data collection for the evacuation of the assigned NEO population.

Another less obvious change is the insertion of statistics node 1 in the network, which permits the collection of data concerning the arrival distribution of convoys. This node was included to allow the authors to model the rail and road interface required to redirect the bulk of evacuees westward when the field was overrun.

Transactions flow through this network in the same manner as described for the previous network model, with the exception of the differences listed above. Source node 130 generates a new release every 3.6125 hours, node 90 transforms these into six simultaneous releases to the Evacuation Points, and so on to queue node 30. Here the evacuees are probabilistically assigned to a pre-flight briefing group with different briefing times of .5 and .7 hours respectively, then on to the C-141/CRAF boarding queue 220, then regular node 80, and two transactions are simultaneously released to statistics node 1 and sink node 2, representing safe arrival in the U.S. The constant service times equal to zero means that both

transactions arrive at sink node 2 at the same time. This feature permits the collection of both between and interval statistics which indicate the time between releases or interarrival times of incoming aircraft and the total time required to move that transaction (group of evacuees) through the network respectively. The former information would be useful to stateside planners responsible for reception of evacuees and their subsequent movement from the aerial port; the latter information is of primary interest to this research effort in determining the time required to evacuate the FRG.

Both network models function in a similar manner except as noted. This concludes the model description. The next section deals with the experimental design.

Research Design for Analysis of the Model

The two networks in Figures 4 and 5 were converted into the programs included in Appendices D and E respectively. These two network models provide the data points of interest to this research effort. The data will be analyzed to determine the effect of different variables of aircraft availability, convoy availability, and weather on the time required to evacuate all noncombatants designated to exit the respective Evacuation Ports. In the process, a search will be conducted for the optimal dependent variable value resulting from the various combinations of independent variables. This analysis design necessitates a search technique in which one experimental factor is varied while the others are held constant.

Analysis of variance will be used to interpret the results of the simulations. Each simulation run of a network consisting of ten iterations will result in three data elements for further analysis. The first is total time required to empty the network; the second is the number of evacuee groups rerouted to the sink node representing transhipment to an alternate Evacuation Port when the current Port is overrun, and the third data element is the percentage of balkers per time period from the queue nodes representing the groups of evacuees exceeding the capacity of the Evacuation Points.

Aircraft availability ranges from 40 to 75 percent for each surface convoy availability of one to five convoys (capacity of 720 people to a convoy as previously specified), and one of two weather conditions (either summer or winter). The weather factor will only affect surface travel times, as previously discussed under the assumptions section. This same sequence of simulations will be run for the Munich network model.

Figure 6 illustrates the various combinations of factors simulated by this research. Each cell would contain ten data elements representing the ten iterations for each combination of factors that constitutes one simulation run. There will be a total of 120 runs, or 1200 iterations for both network models.

This type of research design is a fractional mixed-level factorial design in which the levels of the factors being tested are not the same. For example, six levels of aircraft

Available Convoys	Percent Aircraft Available 40	50	60	65	70	75
1						
2						
3						
4						
5						

Figure 6

Sample Format for Results

availability versus five for convoys and two for weather. The data elements collected from each simulation run were arrayed in the same matrix design illustrated in the previous figure, with each cell containing ten data elements. For example, the data table for the time required to complete evacuation of an Evacuation Port network consists of 60 cells, with 10 separate evacuation times in each cell. This holds true for the data elements representing the number of evacuee groups transhipped when the Ports are overrun or closed by enemy activity, as well as the data elements representing the percentage of balkers per time unit for the Evacuation Points. This is an orthogonal design in which comparisons among means for each cell utilize non-overlapping pieces of information from the experiment.

As mentioned earlier, analysis of variance is the method selected for interpreting the results because its objective is to locate the important independent variables in

this study and determine how they affect the dependent variable. Analysis of variance is actually a test of population sample means with the null hypothesis stated as the means being compared are equal to each other, while the alternate hypothesis is stated as the means being compared are not all equal to each other. This is usually represented as:

$$H_0: \mu_1 = \mu_2 = \ldots = \mu_i$$

where

i = number of means being compared

and

$$H_1: \mu_1, \mu_2, \ldots, \mu_i \text{ are not all equal}$$

The actual test of the null hypothesis lies in the comparison of the between-treatment variance with the within-treatment variance (treatment mean square to error mean square). The variances are derived by dividing the degrees of freedom associated with the respective sums of squares into those sums of squares (between-treatment sum of squares and within-treatment sum of squares). The ANOVA model used in this research can be written as follows:

$$SS = SS_A + SS_B + SS_C + SS_{AB} + SS_{AC} + SS_{BC} + SS_{ABC} + SSE$$

in which A is the weather factor main effect

B is the aircraft availability factor main effect

AB, AC, BC, and ABC are the respective interaction effects of the various factors.

In other words, the total variation in the system is

equal to the sum of the variation due to A, plus the variation due to B, plus the variation due to C, plus the variation due to the interaction of A and B, plus the variation due to the interaction between A and C, plus the variation due to the interaction between B and C, plus the variation due to the interaction among A, B, and C, plus the variation due to random error. The symbol SS denotes sum of squares, which is a measure of variation about a mean.

A simple one factor analysis of variance will be used to demonstrate the technique. For example, the treatment sum of squares is calculated as the sum of all observations within a treatment of the sample size times the square of the difference between a treatment (or level) mean and the grand mean of all observations. This can be represented as:

$$SSTR = \sum_j n(\overline{X}_j - \overline{\overline{X}})^2$$

where n is the sample size

$\overline{X}_j$ is the mean of the j^{th} treatment, and

$\overline{\overline{X}}$ is the grand mean of all observations

As further illustration, assume a sample size of four, an $\overline{X}_j$ of five, seven, and three, and an $\overline{\overline{X}}$ of four, the calculation of SSTR would be as follows:

$$(5 - 4)^2 = 1 \qquad (7 - 4)^2 = 9 \qquad (3 - 4)^2 = 1$$

$$\sum_{j=1}^{3} n(\overline{X}_j - \overline{\overline{X}})^2 = 4(1) + 4(9) + 4(1) = 44$$

This means that the variation due to different levels of a factor is equal to 44. With three levels or treatments, the

degrees of freedom = 3 - 1 = 2, and the variance due to the different levels = 44/2 = 22. The error sum of squares is calculated somewhat differently in that it is a measure of the sum (for all treatments) of the deviation of observations within each treatment about their respective treatment means. It can be represented as:

$$SSE = \sum_j \sum_i (X_{ij} - \overline{X}_j)^2$$

where

X_{ij} is the observation in row i and column j and

$\overline{X}_j$ is the mean of column j

For illustration, assume the following table of observations:

	Treatment		
Observation #	1	2	3
1	3	7	4
2	4	9	2
3	6	4	5
4	7	8	1
Total	20	28	12
Mean	5	7	3

The calculation of SSE would be as follows:

Treatment 1		Treatment 2		Treatment 3	
$(X_{ij}-X_j)$	$(X_{ij}-X_j)^2$	$(X_{ij}-X_j)$	$(X_{ij}-X_j)^2$	$(X_{ij}-X_j)$	$(X_{ij}-X_j)^2$
3-5=-2	4	7-7=0	0	4-3= 1	1
4-5=-1	1	9-7= 2	4	2-3= 1	1
6-5= 1	1	4-7=-3	9	5-3= 2	4
7-5= 2	4	8-7= 1	1	1-3=-2	4
	10		14		10

$$SSE = \sum_{j=1}^{3} \sum_{i=1}^{4} (X_{ij} - X_j)^2 = 10 + 14 + 10 = 34$$

This means that the variation due to random error is equal to 34. The degrees of freedom associated with SSE is equal to the number of treatments times one less than the sample size in each treatment, or 3(4 - 1) = 9. This means the error mean square or variance due to random error = 34/9 = 3.78. For this simple example, the total variation = 44 + 34 = 78, with 11 degrees of freedom. The true test, however, lies in the comparison of the treatment mean square and the error mean square; in this case, 22/3.78 = 5.82. This is the calculated F, our test statistic, and it must be compared to a value from an appropriate table of F distributions (in this case, assume that $1 - \alpha = .95$). For the sample degrees of freedom of 2 and 9, the appropriate F value is 4.26. Since 5.82 is greater than 4.26, we reject the null hypothesis that the treatment means are equal, and recognize that a significant difference exists which requires additional tests to pinpoint the treatment or level that had the significantly different effect.

The test applied in this research to identify the significant effects is Tukey's Honestly Significant Difference (HSD) Test (15). The HSD test is designed to make all pairwise comparisons among means, with a comparison involving two means declared to be significant if it exceeds HSD, which is given by:

$$HSD = q_{\alpha,\upsilon}\sqrt{\frac{MSE}{n}}$$

where q is obtained from a table of the distribution of studentized range statistic which is entered via the degrees of freedom for the error mean square (MSE) and K, the number of treatment levels in the experiment. MSE is the calculated error mean square from the analysis of variance; and n is the sample size for each treatment level. An overall test of the hypothesis that $\mu_1 = \mu_2 = \ldots = \mu_i$, where i is the number of means being compared, is provided by a comparison of the largest pairwise difference between means with the critical value for HSD. If this difference exceeds HSD, the overall null hypothesis is rejected and the comparison declared significant at the selected α level. This means that the treatment represented by the larger mean has had a significant effect on the dependent variable of the system being analyzed. A simple example of a Tukey table is illustrated below using the same means and error mean square from the analysis of variance example.

	$\bar{X}_3$	$\bar{X}_1$	$\bar{X}_2$
$\bar{X}_3=3$	-	2	4*
$\bar{X}_1=5$		-	2
$\bar{X}_2=7$			-

$$HSD = q_{.05,9}\sqrt{\frac{MSE}{n}} = 3.95\sqrt{\frac{3.78}{4}} = 3.84$$

The difference between the largest and smallest means is equal to 4 in this example, and since it exceeds HSD - 3.84, the overall null hypothesis is rejected and treatment two is

identified as having a significant effect.

This concludes the discussion of the research design used to analyze the model. The next chapter contains the results of the simulation runs of the network models and a discussion of application of the techniques described above to analyze those results. It also contains discussion on the overall validation of the models. Internal verification was accomplished as follows:

1) A test run of the first portion of the networks was done as a simplified network to insure that the six transactions created by node 90 in each network duplicated the travel time assigned to each transaction between source node 130 and node 90. This was done as a source node releasing transactions to a node similar to 90 that releases six transactions to three queue nodes branching to a common sink node.

2) A test run was made of a source node releasing transactions to a regular node, with conditional take-first branching to two queue nodes which release transactions to a common sink node. This verified the model's ability to simulate increased availability of airlift assets from overrun forward airfields.

3) A test run was made of a source node releasing transactions to a regular node which sent duplicate transactions to a statistics node and a sink node, with the statistics node also releasing a transaction to the sink node. This verified the simultaneous arrivals at the sink node when using constant parameters of zero travel time between the affected

nodes at the end of the Munich network model.

In summary, this chapter has described the assumptions necessary to deal with the complexity of the overall system before transforming it into a network model. The working models for a military and civilian airfield were described in detail and the research design for analyzing the system was presented. Analysis of variance, particularly three-way analysis of variance as used in this research, is subject to certain limitations. The confounding characteristics associated with fractional factorial designs mask the effect identified by the analysis of variance. This occurs to the point where you cannot be sure whether it is the main effect, the interaction effect, or some additive combination. In fact, with a small number of factors (three in this research), the confounding of two or more effects is bound to prevent discrimination between main effects and important interactions (17). The Tukey HSD test uses a range statistic and, for most sets of data, leads to the same decision concerning the overall null hypothesis as the F statistic used in the analysis of variance. The F statistic generally provides a more powerful test of a false null hypothesis than does the range statistic (15:89). Neither of the tests do more than identify significant differences among means. The interpretation of those differences is a subjective matter, and subject to distortion simply because it is subjective. This will be discussed further in the next chapter along with the previously mentioned subjects.

CHAPTER IV

RESULTS AND ANALYSIS

Overview

This chapter contains the results of the application of the methodology discussed in the previous chapter. Twelve hundred observations were generated by the two simulation models described in Chapter III, 600 for Rhein-Main and 600 for Munich. The results are summarized as tables of means, with each mean averaged over the ten iterations run for each combination of weather, number of convoys, and aircraft availability. A three-way analysis of variance (ANOVA) was run on the set of data elements (600 observations to a set) for the two models' time to empty. A two-way ANOVA was run on the number of groups transhipped (rerouted when destination Port was overrun or closed), and a three-way ANOVA was run on the percent of balkers per time unit who exceeded the queue capacity of the Evacuation Points. The three-way ANOVA was used to indicate significant variance caused by main effects of treatments, or interactions of treatments for all three factors. The two-way was used for the same reason, but for only two factors. An application of Tukey's Honestly Significant Difference (HSD) Test is illustrated, using the data set of mean times required to evacuate the network

models. The chapter concludes with an overall analysis discussion.

Time Required to Empty Networks

Results. The data elements for evacuation time of each network model were collected for each combination of weather, number of convoys, and percent availability of aircraft; means were calculated for each cell and arrayed according to the illustration in Figure 6 of Chapter III. The treatment means for the Rhein-Main model are shown in Tables I and II, and those for the Munich model are in Tables III and IV.

Analysis. By observation, it is obvious that most of the cell means are different. The question is whether or not these differences are statistically significant. Using a three-way analysis of variance (because of the three factor levels), the hypothesis being tested is:

H_0: all means are equal, with the alternate hypothesis as

H_1: not all means are equal

As stated in Chapter III, the actual test of the null hypothesis lies in the comparison of the between-treatment variance with the within-treatment variance. In the case of research involving more than one factor, the interaction of two or more factors is considered to be a treatment which must also be tested. This research involves three main treatments and four interaction treatments; therefore, there

TABLE I

Mean Evacuation Times (Hours) For

Rhein-Main in Winter

Number of Convoys	Percent Aircraft Available					
	40	50	60	65	70	75
1	900	900	900	900	900	900
2	540	510	543	515	511	509
3	533	435	411	412	390	411
4	535	436	384	359	337	345
5	538	437	385	359	340	328

TABLE II

Mean Evacuation Times (Hours) For

Rhein-Main in Summer

Number of Convoys	Percent Aircraft Available					
	40	50	60	65	70	75
1	536	535	534	535	535	535
2	530	528	378	353	338	335
3	532	436	379	353	330	320
4	535	436	380	356	334	323
5	538	438	384	357	340	307

TABLE III

Mean Evacuation Times (Hours) For

Munich in Winter

Number of Convoys	Percent Aircraft Available					
	40	50	60	65	70	75
1	900	894	890	897	900	900
2	900	796	619	544	589	522
3	900	740	617	535	543	476
4	900	725	628	545	532	476
5	880	705	647	524	508	470

TABLE IV

Mean Evacuation Times (Hours) For

Munich in Summer

Number of Convoys	Percent Aircraft Available					
	40	50	60	65	70	75
1	900	886	709	571	564	532
2	900	701	576	552	553	528
3	900	707	621	581	547	475
4	900	714	617	580	546	479
5	900	746	649	579	588	447

must be seven comparisons performed to test the null hypothesis. The test statistic used is:

$$F^* = \frac{MS(x)}{MSE}$$

where MS(x) represents the treatment mean square and MSE represents the error mean square. As mentioned in Chapter III, the variance due to A (the weather factor), B (aircraft availability), C (the number of convoys), AB (the interaction of weather and aircraft), AC (the interaction of weather and convoys), BC (the interaction of aircraft and convoys), and ABC (the interaction of all three) were tested to see if any of the seven treatments had a significant effect. The calculations of the treatment mean squares and error mean squares for a three-factor test are determined in an iterative process similar to that illustrated in the last chapter for a one-factor test, and will not be discussed in this research paper. An excellent discussion on three-way ANOVA may be found in the Neter-Wasserman text on statistical models (17). A Honeywell library analysis of variance program, ANVA5, in the CREATE computer system at the Air Force Institute of Technology was used to develop the analysis of variance table shown in Table V.

The level of risk for concluding a significant effect existed, when it did not, was set at $\alpha = .05$. The computer program provided the grand mean and first four columns of the table. The fifth column of test statistics was derived by dividing the error mean square of 116.3 into each of the

TABLE V

Three-Way Analysis of Variance -

Rhein-Main Model (Evacuation Times)

Grand Mean = 4.765400E 02

Source	SS	DF	M-SQUARE	F*=MS(x)/MSE	F
A	8.357191E 05	1	8.357191E 05	7.1853E 03	(.95,1,540) = 3.84
B	6.911133E 05	5	1.382227E 05	1.1884E 03	(.95,5,540) = 2.21
C	4.485505E 06	4	1.121376E 06	9.6413E 02	(.95,4,540) = 2.37
AB	4.371898E 04	5	8.743796E 03	7.518 E 01	(.95,5,540) = 2.21
AC	1.333104E 06	4	3.332761E 05	2.8654E 03	(.95,4,540) = 2.37
BC	2.264449E 05	20	1.132224E 04	9.735 E 01	(.95,20,540)= 1.57
ABC	7.729196E 04	20	3.864598E 03	3.323 E 01	(.95,20,540)= 1.57
SSE	2,791639E 04	240.0	1.163183E 02		
SST	7.720814E 06	299.0	2.582212E 04		

treatment mean squares (since the output was in scientific notion, so are the calculations). The sixth column of values were extracted from a standard table of critical values for the F distribution. The test statistic for each treatment was compared to the adjoining critical value according to the following decision rule:

$$\text{if } F^* \leq F\ (.95,\ df_{(x)},\ 540), \text{ conclude } C_1$$

$$\text{and if } F^* > F\ (,95,\ df_{(x)},\ 540), \text{ conclude } C_2$$

where

C_1: all variance associated with (x) treatment = 0

and C_2: all variance associated with (x) treatment $\neq$ 0

If C_1 is concluded, then treatment (x) had no significant effect, but if C_2 is concluded, treatment (x) has had a significant effect on the network model. According to the figures in Table V, every treatment had a significant effect on the model, and additional analysis is required to pinpoint which treatment(s) is (are) most significant. An illustration of one such test is included near the end of this chapter.

The ANVA5 routine was used to develop a similar analysis of variance table for the Munich network model. It is shown in Table VI. The test statistics in the fifth column were derived by dividing each treatment mean square by the error mean square of 161.1. The same decision rule was applied to see if there were any significant differences in variance associated with the treatments in this model. As in the other model, every treatment had a significant effect and the null

TABLE VI

Three-Way Analysis of Variance -

Munich Model (Evacuation Times)

Grand Mean = 6.702750E 02

Source	SS	DF	M-SQUARE	F*=MS(x)/MSE	F
A	4.748090E 04	1	4.748090E 04	2.9467E 02	(.95,1.540) = 3.84
B	1.893790E 06	5	3.787579E 05	2.3506E 03	(.95,5,540) = 2.21
C	4.767365E 05	4	1.191841E 05	7.3968E 02	(.95,6,540) = 2.37
AB	2.464710E 04	5	4.929420E 03	3.059 E 01	(.95,5,540) = 2.21
AC	2.023378E 05	4	5.058444E 04	3.1394E 02	(.95,4,540) = 2.37
BC	1.184193E 05	20	5.920965E 03	3.675 E 01	(.95,20,540)= 1.57
ABC	1.341337E 05	20	6.707237E 03	4.163 E 01	(.95,20,540)= 1.57
SSE	9.66750CE 03	60.0	1.611250E 02		
SST	2.907224E 06	119.0	2.443045E 04		

hypothesis was rejected, indicating the need for additional analysis in order to pinpoint the most important treatments.

Number of Groups Transhipped

Results. The data elements for number of groups rerouted when their respective Evacuation Port was overrun or closed were collected and arranged in the same manner as for the data on time required to empty the networks. Tables VII and VIII represent the groups rerouted when Rhein-Main shut down, and Tables IX and X represent the groups rerouted from Munich. Each group contains 720 people.

The entries in Tables VII - X were obtained from the first iteration of each run of ten iterations for the network models, and may not represent true mean values for the number of groups being rerouted. However, the relative magnitudes of the values recorded are of interest rather than the values themselves. For instance, in referring to Tables VII and VIII, all evacuees were removed from the Rhein-Main network without transhipment with a policy mix of two or more convoys during the summer, as compared to winter when four or more convoys were required to empty the network without transhipment. The contrast is more pronounced for the results of the Munich model.

Analysis. A two-way ANOVA was performed on this data in the same way as described previously for the three-way. The CREATE library program produced the first four colums of the ANOVA table shown in Table XI for Rhein-Main and Table XII for Munich. A two-way ANOVA was used because winter was

TABLE VII

Evacuee Groups Rerouted From

Rhein-Main in Winter

Number of Convoys	Percent Aircraft Available					
	40	50	60	65	70	75
1	150	147	150	146	147	146
2	91	80	87	77	92	87
3	10	15	30	27	10	29
4	0	0	0	0	0	0
5	0	0	0	0	0	0

TABLE VIII

Evacuee Groups Rerouted From

Rhein-Main in Summer

Number of Convoys	Percent Aircraft Available					
	40	50	60	65	70	75
1	83	86	81	90	85	84
2	0	0	0	0	0	0
3	0	0	0	0	0	0
4	0	0	0	0	0	0
5	0	0	0	0	0	0

TABLE IX

Evacuee Groups Rerouted From

Munich in Winter

Number of Convoys	Percent Aircraft Available					
	40	50	60	65	70	75
1	202	174	192	123	194	178
2	177	160	123	48	177	174
3	157	153	150	150	153	152
4	130	126	124	137	124	132
5	119	131	99	104	100	111

TABLE X

Evacuee Groups Rerouted From

Munich in Summer

Number of Convoys	Percent Aircraft Available					
	40	50	60	65	70	75
1	428	329	181	173	174	175
2	126	125	124	123	176	121
3	76	77	74	73	24	123
4	22	24	25	25	22	19
5	0	0	0	0	0	27

obviously the worst case for evacuating noncombatants before the Ports closed, and it was desired to collapse the weather factor in order to determine whether the number of convoys or percent aircraft were most significant in determining how many groups were rerouted. For a two-way ANOVA, there are three treatment effects, two main and one interaction. In this case, they are A (percent aircraft available), B (number of convoys), and AB (the interaction between aircraft and convoys). As in the discussion on the analysis of variance for time to empty the networks, the fifth column figures were derived by dividing the error mean square term into the respective treatment mean squares, and the sixth column of critical values was obtained from a standard table of critical values for the F distribution. As in the previous test, the hypotheses being tested are:

H_0: all treatment means are equal

H_1: not all means are equal

A similar decision rule was applied in this case as well:

if $F^* \leq F\,(.95,\ df_{(x)},\ 30)$, conclude C_1

if $F^* > F\,(.95,\ df_{(x)},\ 30)$, conclude C_2

where

C_1: all variance associated with (x) treatment = 0

C_2: all variance associated with (x) treatment $\neq$ 0

If C_2 is concluded for any treatment, then H_0 must be rejected because the treatment has had a significant effect on the variable of interest, the number of groups rerouted, and the means

TABLE XI

Two-Way Analysis of Variance -

Rhein-Main Model (Groups Rerouted)

Grand Mean = 3.38333E 01

Source	SS	DF	M-SQUARE	F*=MS(x)/MSE	F
A	2.993301E 01	5	5.986601E 00	5.07 E 03	(.95,5,30) = 2.9
B	1.167235E 05	4	2.918988E 04	2.47 E 01	(.95,4,30) = 3.13
AB	2.979000E 02	20	1.489500E 01	1.26 E 02	(.95,20,30) = 2.07
SSE	3.545100E 04	30.0	1.181700E 03		
SST	1.525023E 05	59.0	2.584785E 03		

TABLE XII

Two-Way Analysis of Variance -

Munich Model (Groups Rerouted)

Grand Mean = 1.190000E 02					
Source	SS	DF	M-SQUARE	F*=MS(x)/MSE	F
A	1.398500E 04	5	2.797000E 03	6.25 E 01	(.95,5,30) = 2.9
B	1.721625E 05	4	4.304063E 04	9.62 E 00	(.95,4,30) = 3.13
AB	3.659350E 04	20	1.829675E 03	4.09 E 01	(.95,20,30) = 2.07
SSE	1.342490E 04	30.0	4.474967E 03		
SST	3.569900E 05	59.0	6.050678E 03		

are different.

The comparison of the test statistics and critical values reveals that only the number of convoys factor has a significant effect on the number of groups rerouted for either the Rhein-Main or Munich models. An interaction effect can be postulated between the two factors of weather and number of convoys. Hence a Tukey HSD Test would not be applicable. However, as mentioned earlier in reference to the tables for Rhein-Main, the minimum number of convoys required may be determined by observation as four in winter and two in summer (each convoy, whether bus or truck, must carry 720 people). This does not seem true for the Munich model, in that the ANOVA table indicates that five or more convoys are required in summer, and a number in excess of the experiment's parameters is required in winter.

Percent Balkers Per Time Unit at Evacuation Points

Results. The Q-GERT analysis program includes a section in which average balking statistics are reported. These statistics represent the transactions averaged over all ten iterations for each run which cannot enter a queue because it is full, and are reported as percent balkers per time unit at the respective nodes. These data points are shown in Tables XIII and XIV for Rhein-Main as individual entries for nodes 230, 240, and 250 respectively. All the entries for the Munich network model were further averaged into one data point because there were so few entries, and are shown on Tables XV

AD-A090 734 AIR FORCE INST OF TECH WRIGHT-PATTERSON AFB OH SCHOOL--ETC F/G 15/5
A STUDY AND MODEL OF THE NONCOMBATANT EVACUATION OPERATION IN T--ETC(U)
JUN 80 H W GULLETT, T N STIVER

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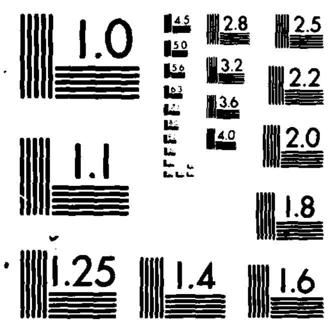


MICROCOPY RESOLUTION TEST CHART
NATIONAL BUREAU OF STANDARDS-1963-A

TABLE XIII

Rhein-Main Percent Balkers Per

Time Unit in Winter

Number of Convoys	Percent Aircraft Available					
	40	50	60	65	70	75
	.0631	.0637	.0629	.0628	.0628	.0629
1	.0630	.0634	.0627	.0631	.0631	.0627
	.0631	.0635	.0632	.0629	.0627	.0629
	.0918	.0950	.0908	.0928	.0914	.0926
2	.0914	.0936	.0908	.0926	.0908	.0931
	.0909	.0936	.0908	.0928	.0918	.0924
	.0746	.0919	.1021	.1023	.1013	.1015
3	.0749	.0905	.1021	.1016	.1011	.1017
	.0761	.0912	.1014	.1023	.1032	.1019
	.0648	.0798	.0830	.0977	.0950	.1008
4	.0642	.0793	.0838	.0952	.0932	.1005
	.0653	.0789	.0848	.0957	.0938	.1022
	.0435	.0615	.0625	.0670	.0703	.0621
5	.0444	.0622	.0609	.0679	.0718	.0630
	.0444	.0610	.0619	.0651	.0709	.0625

and XVI.

Analysis. To interpret Tables XIII - XVI in terms of evacuees who exceed the capacity of respective Evacuation Points, it is necessary to refer to the tables for the times required to empty the systems. As an illustration, consider the Rhein-Main model, where the worst case occurs during winter at the combination of three convoys and 65 percent

TABLE XIV

Rhein-Main Percent Balkers Per

Time Unit in Summer

Number of Convoys	Percent Aircraft Available					
	40	50	60	65	70	75
1	.0906	.0909	.0908	.0912	.0917	.0909
	.0909	.0916	.0912	.0921	.0917	.0909
	.0908	.0912	.0914	.0915	.0908	.0907
2	.0637	.0786	.0891	.0964	.0999	.0962
	.0643	.0791	.0893	.0947	.0984	.0951
	.0633	.0793	.0880	.0950	.0993	.0923
3	.0338	.0436	.0482	.0517	.0580	.0578
	.0344	.0422	.0501	.0540	.0541	.0593
	.0340	.0422	.0490	.0517	.0547	.0581
4	.0060	.0078	.0071	.0101	.0089	.0105
	.0071	.0076	.0092	.0123	.0083	.0118
	.0054	.0066	.0089	.0104	.0093	.0090
5	0	0	0	0	0	0

aircraft. Node 230 balks .1023 groups each hour for 412 hours (from the same cell in Table I). Likewise, node 240 balks .1016 and node 250 balks .1023 per hour. This means an average of 42 groups are not able to enter the respective Evacuation Points during the operation, or a total of 126 groups altogether. This works out to approximately 91,000 people, or 44 percent of the total number designated to evacuate through Rhein-Main. In order to determine which factor had the most effect on this variable, a three-way ANOVA was run through

TABLE XV

Munich Percent Balkers Per

Time Unit in Winter

Number of Convoys	Percent Aircraft Available					
	40	50	60	65	70	75
1	.0035	.0014	.0079	.0023	.0089	.0089
2	.0011	.0011	.0011	0	.0022	0
3	0	0	0	0	0	0
4	0	0	0	0	0	0
5	0	0	0	0	0	0

TABLE XVI

Munich Percent Balkers Per

Time Unit in Summer

Number of Convoys	Percent Aircraft Available					
	40	50	60	65	70	75
1	.0011	.0011	.0011	.0017	.0021	.0019
2	0	0	0	0	.0037	0
3	0	0	0	0	0	0
4	0	0	0	0	0	0
5	0	0	0	0	0	0

TABLE XVII

Three-Way Analysis of Variance - Rhein-Main Model (Percent Balkers)

Grand Mean = 6.322767E 02

Source	SS	DF	M-SQUARE	F*=MS(x)/MSE	F
A	4.895949E 02	1	4.895949E 02	9.02E 02	(.95,1,240) = 3.84
B	4.437658E 03	5	8.875316E 04	1.63E 02	(.95,5,240) = 2.21
C	8.077227E 02	4	2.019307E 02	3.72E 03	(.95,4,240) = 2.37
AB	1.865510E 04	5	3.731019E 05	6.87E 00	(.95,5,240) = 2.21
AC	6.574142E 02	4	1.643535E 02	3.03E 03	(.95,4,240) = 2.[illegible]
BC	2.211097E 03	20	1.105548E 04	2.04E 01	(.95,20,240) = 1.57
ABC	3.058204E 03	20	1.529102E 04	2.82E 01	(.95,20,240) = 1.57
SSE	6.516295E 04	120.0	5.430246E 06		
SST	2.060183E 01	179.0	1.150940E 03		

the CREATE library program ANVA5. As previously mentioned, there are three main effects and four interaction effects to examine. The library program provided the first four columns shown in Table XVII; the additional figures were obtained as before.

As with the three-way results for the first data set, with the same hypothesis being tested and the same decision rules, all treatments are considered to have a significant effect on the response variable. Again, additional testing is indicated to pinpoint which treatments are most significant. One such test is illustrated in the next section.

Tukey HSD Test of Mean Times Required to Empty the Networks

The function of the Tukey Test was described in the previous chapter, using a one-factor example. The Tukey Test is used to examine main effects and is incapable of testing interactions. However, by collapsing the data for two factors, we may apply the Tukey HSD Test to the main effect of the remaining factor. This was done by taking the absolute differences between the means for winter and summer evacuation times for Rhein-Main. The results is shown in Table XVIII. Munich is illustrated in Table XIX.

The critical value is obtained from a table of Percentage Points of the Studentized Range based on the degrees of freedom associated with the respective error mean square and the number of treatment levels in the experiment. In this case, there are 60 degrees of freedom and 30 treatment levels,

TABLE XVIII

Tukey Test of Means

Rhein-Main Model

Number of Convoys	Percent Aircraft Available					
	40	50	60	65	70	75
1	364	341	366	365	365	365
2	10	18	190	162	173	174
3	1	1	32	59	60	91
4	0	0	4	3	3	22
5	0	1	1	2	0	21

TABLE XIX

Tukey Test of Means

Munich Model

Number of Convoys	Percent Aircraft Available					
	40	50	60	65	70	75
1	0	8	19	326	336	368
2	0	95	43	8	36	6
3	0	33	4	46	4	1
4	0	11	11	35	14	3
5	20	41	2	55	80	23

so the critical value is 5.01 at the .95 confidence level (through interpolation) for both models.

For each instance where the value indicated in the cells of the previous tables exceeds the Tukey critical value, those combinations of aircraft and surface convoys are significantly affected by the weather factor. The adjoining cells of significant effect are a region of interest for policy decisions concerning the appropriate mix of convoys and aircraft for different weather conditions. The region of cells indicating no significant weather effect are of interest for further testing to determine whether the variance in these combinations is due to the main effects or interactions of aircraft and convoys (regardless of weather).

Overall Analysis

With an overrun time of 336 hours, only six policy mixes resulted in the Rhein-Main network being emptied during summer road conditions, and only one policy mix during winter road conditions. None of the simulated combinations emptied the Munich network under either weather factor before its overrun time of 120 hours. The weather factor is obviously having a significant effect on the response variable. This was confirmed by the ANOVA and Tukey results. The ANOVA also indicated significant effects from the interaction treatments of the three factors, but the Tukey could not be used to confirm this or pinpoint the most significant effects. In fact, the interactions could very well be masking main treatment

effects for both models.

By collapsing the weather factor for the analysis of the number of groups transhipped, it was shown that the main treatment effect for number of convoys has a significant effect, and that aircraft and the interaction of the two did not. This appears logical when you consider that the primary weather effect for the parameters modeled was on surface road travel times rather than delays in flight times. The Rhein-Main model minimized group transhipments with two or more convoys during summer, and four or more convoys during winter. The Munich model required transhipment even with five convoys during winter, but minimized transhipments with five or more convoys during summer.

The Munich model results clearly indicate a worst case for balkers per time period for winter conditions. However, the Rhein-Main model results are less clear by direct observation. For instance, a trend is indicated in the summer results in which the number of balkers appear to increase from left to right, as the percent of aircraft increases. This could be explained by referring to the tables for mean times to empty the networks and observing that there is a decrease in times from left to right, as aircraft increase. Assuming a steady-state number of balkers per network, a decrease in times would naturally mean an increase in balkers per unit time. This rationale may also be applied to differences between rows, from top to bottom, because of shorter empty times; hence, increased balkers per unit time.

In comparing the model to the actual system, it may be postulated that the balking of groups from the Evacuation Points is the result of two factors not tested in the existing current model. Those are the population of noncombatants assigned for evacuation through the respective Evacuation Ports and the queue capacity limit of 43,200 placed on each Evacuation Point. A planner for the actual system may determine either factor to be sensitive and vary them in an analysis similar to that demonstrated in this report. Additional model parameters must be manipulated to determine the significant factors involved. This study has established a base from which to build on additional research parameters. The next chapter contains conclusions and recommendations to aid further research.

CHAPTER V

CONCLUSIONS AND RECOMMENDATIONS

Overview

The preceding chapters have answered the research questions identified in the first chapter. "What is the structure of the NEO System?" was answered in Chapter II by describing the structure of the existing NEO System. The second research question asked what the interactions between and among the system's major subsystems were. That was also answered in Chapter II. The third question asked which systems were most sensitive to change. The factors within the model were tested in Chapter IV to determine which were most sensitive to change. The objective of this research was to develop the model described in Chapter III as an aid to planners for allocating the resources necessary to bring off this large-scale operation. This chapter summarizes the findings and conclusions of this research and offers recommendations for additional action.

Conclusions

The NEO System, although seemingly overwhelming, can be modeled using the techniques of this thesis. A model of that system can be used to predict evacuation times for portions of the FRG or the entire country. The models described

in this thesis and their simulated results are not directly applicable to the problems faced by planners responsible for the real system. However, the concepts and some assumptions are applicable to those problems. The addition of classified or sensitive numbers as parameters in the models presented in this thesis will increase the validity of the network models. The inclusion of additional factors for sensitivity analysis will also increase the validity of the models. Defense planners should not attempt to enlarge the model by too many factors. As Shannon says:

> The tendency is nearly always to simulate too much detail rather than too little. Thus, one should always design the model around the questions to be answered rather than imitate the real system exactly. Pareto's law says that in every group or collection there exists a vital few and a trivial many. Nothing really significant happens unless it happens to the vital few [27:27].

This thesis has examined a "vital few." Weather is a significant factor whose effect is apparent in the differences between the tables for the time to empty the networks. The ANOVA tests have confirmed that the number of convoys and percent of aircraft also are significant factors, and that an interaction effect between the factors is not only present, but is significant as well. The sensitivity of the number of convoys and aircraft availability combinations was most apparent in the number of groups requiring rerouting because of the failure to evacuate them before the Ports were closed. Planners involved in resolving the problems of the real system would be well advised to consider the effects of

vehicle availability and ground fuels for those vehicles before dismissing that portion of the system from any detailed planning. The percent balkers per time period results are inconclusive, as previously discussed. However, additional detailed parameters for the Evacuation Points might make this data more relevant to the problem at hand.

In general, the results of this thesis lead to the conclusion that a large number of surface transports dedicated to the movement of evacuees will be required, regardless of the number of aircraft involved in the operation. The simulation results also imply that the Evacuation Points, or assembly areas, cannot accommodate the large number of noncombatants designated to process through them enroute to the Evacuation Ports. This may or may not be the case when the actual classified numbers are inserted in the models. It was true in the research presented. The differences between the evacuation mean times for Rhein-Main and Munich, as modeled, are due in part to the shorter time before the Port is overrun or closed, but more likely is the probability that the difference is partially due to the lack of C-5 aircraft being used in the Munich network model. This factor bears additional consideration by DOD planners before assigning airlift resources strictly to military airfields.

Congressmen and the public at large have often voiced the opinion that there are too many military dependents overseas (32:6). Military leaders feel that limits or ceilings on the number of dependents allowed overseas will lower

morale and result in travel delays for those who do go (20: 8). Research demonstrates that the number of dependents in the FRG are outnumbered by tourists, State Department personnel, and American workers living overseas. The most significant effect would result from not allowing any of the dependents to go overseas. That would reduce the potential NEO population by approximately 20 percent. That, of course, is not a recommendation of this research. Those are presented in the next section.

Recommendations

Based on the results of this thesis effort, further research and expansion of the model is strongly recommended. A recent announcement was made that a simulated evacuation is scheduled for the coming summer involving 2,000 dependents (30:24). Planners for this exercise should be given an opportunity to use this model as a tool for predicting their simulated evacuation times. This will help test the validity of the model and provide additional data for NEO planners. It is further recommended that additional exercises of this nature continue to be scheduled on a regular basis.

In addition, the Defense Department should approve the recently submitted Army plan for flying U.S. dependents back to the U.S. onboard Reforger Exercise transports this fall (30:24). The experience would be invaluable for NEO planners and validate this model.

A further recommendation is that the planners in the

FRG secure convoy assets by contract for NEO use and seriously consider use of the rail system for rapidly moving large numbers of non-combatants away from the eastern portions of the FRG. As demonstrated in the Munich model, convoys did not prove effective. In addition, consideration should be given to the relocation of existing housing areas further west and rotating troops between rear and forward garrisons. This would help reduce the exposure of non-combatants to a rapidly advancing battle area, yet still permit an accompanied tour to the FRG. Additionally, the State Department should prepare a booklet advising tourists of the existence of the NEO plan and the appropriate actions in case of activation of the plan. This booklet could be distributed along with their passports or visas prior to their departure from the U.S.

Certain components of the system could be incorporated in future research of this topic. The following are recommended for consideration as potential sources of information for those components.

1. Total number of Evacuees - population count by DOD installation and State Department planning reports by embassy region (40).
2. Port locations - arrival destinations of augmentation forces (39).
3. Fuel reserves - inventory figures from Fuels Management Division at each DOD installation.
4. In-place MAC aircraft - estimates available from Headquarters, MAC, Operations and Plans (12).

5. Weather - stochastic projections from historical data collected by MAC Air Weather Service (12)

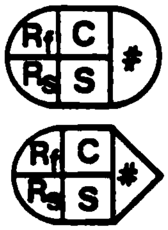
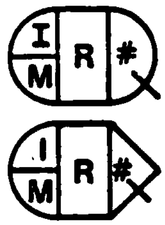
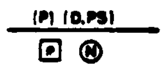
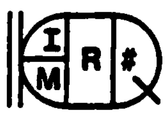
Summary

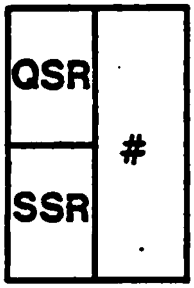
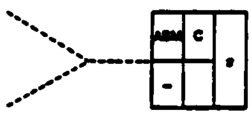
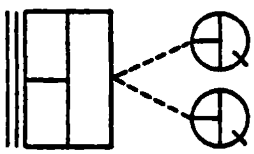
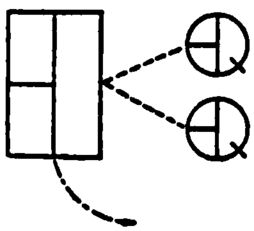
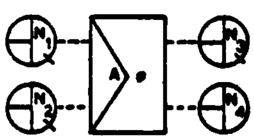
This research has demonstrated that it is possible to model an extremely complex system like the Noncombatant Evacuation Operation. The key question then is whether or not that model is valid, or as one source says, "Do the results make sense [5]?" In this case, the answer is in the affirmative. A great potential exists for developing this initial attempt into an effective information and decision support system. NEO planners should expand the model to improve their ability to anticipate problems and improve the system.

APPENDIX A

Q-GERT SYMBOLS AND TERMS

The following symbols and terms have been reproduced from Pritsker's text on modeling and analysis of systems by using Q-GERT networks (22). The first two nodes shown may be designated as regular nodes by deleting the S value, otherwise they are statistic nodes. The rest of the symbols are self-explanatory.

Symbol	Definition
	R_f is the number of incoming transactions required to release the node for the first time. R_s is the number of incoming transactions required to release the node for all subsequent times. C is the criterion for holding the attribute set at a node. S is the statistics collection type or marking. # is the node number.  indicates deterministic branching from the node.  indicates probabilistic branching from the node.
	I is the initial number of transactions at the Q-node. M is the maximum number of transactions permitted at the Q-node. R is the ranking procedure for ordering transactions at the Q-node. # is the Q-node number.
	Pointer to a source node or from a sink node.
	P is the probability of taking the activity (only used if probabilistic branching from the start node of the activity is specified). D is the distribution or function type from which the activity time is to be determined. PS is the parameter set number (or constant value) where the parameters for the activity time are specified. # is the activity number N is the number of parallel servers associated with the activity (only used if the start node of the activity is a Q-node).
	Routing of a transaction that balks from a Q-node. This symbol can not emanate from a regular node.
	Blocking indicator (only used with Q-nodes that can force preceding *service* activities to hold transactions because the Q-node is at its maximum capacity).

Symbol	Concept	Definition
	Selector node or S-node	QSR is the queue selection rule for routing transactions to or from Q-nodes (see Table 5-2). SSR is the server selection rule for deciding which server to make busy if a choice exists (see Table 5-3). # is the S-node number.
	Routing Indicator	Routing indicator for transaction flow to or from Q-nodes to S-nodes or Match nodes
	Assembly by S-nodes	ASM is the queue selection rule that requires transactions to be assembled from two or more queues.
	Blocking	Blocking at an S-node.
	Balking	Balking from an S-node.
	Match Node	# is the match node number. Transactions are routed from N_1 to N_3 and N_2 to N_4 when a match occurs. A is the attribute number on which the match is to be made

APPENDIX B

NEO SYSTEM INTERRELATIONSHIPS

NEO SYSTEM INTERRELATIONSHIPS

The series of charts below illustrate the interrelationships among and between the various subsystems of the overall NEO system. The factors under each major component either affect or are affected by the components indicated by Roman numerals as follows:

I. NEO Population
II. Evacuation Ports
III. Evacuation Points
IV. Road Networks
V. Railroad Networks
VI. Aircraft
VII. Supplies
VIII. Political/Military Environment
IX. Weather
X. Communications

I. NONCOMBATANT POPULATION

Factors	Interrelationships
Total Number	VIII
Number at Evacuation Points	III, IV, V, VIII, IX, X
Number at Evacuation Ports	III, IV, V, VI, VII, VIII, IX, X

II. EVACUATION PORTS

Factors	Interrelationships
Number of Evacuees	I, III, IV, V, VI, VII, VIII, IX, X
Number of Available Aircraft	III, VI, VII, VIII, IX, X
Aircraft Arrival and Departure Times	VI, VII, VIII, IX, X
Arrival Times of Evacuees	I, III, IV, V, VI, VIII, IX, X
Fuel Reserves	IV, V, VII, VIII, IX, X
Aircraft Maintenance Capability	IV, VI, VII, VIII, IX, X
Incoming Troops	IV, V, VI, VIII, IX, X
Passenger Handling Equipment	VI, IX
Manpower for Processing of Evacuees	I, III, IV, V, VIII, IX, X
Security Control (Traffic, Law Enforcement) Base Security	I, III, IV, V, VI, VIII, IX X
Food, Water	I, III, IV, V, VI, VII, VIII IX, X
Health, Sanitation	I, III, VII, IX, X
Facilities	I, III, VII, IX

III. EVACUATION POINTS

Factors	Interrelationships
Number of Evacuees	I, II, IV, V, VI, VII, VIII IX, X
Arrival and Departure Times of Evacuees	I, II, IV, V, VI, VIII, IX, X
Distance from Evacuation Ports	IV, V, VI, VIII, IX, X
Fuel Reserves	IV, V, VII, VIII, IX, X
Manpower for Processing Evacuees	I, III, IV, V, VIII, IX, X
Security Control	I, II, IV, V, VIII, IX, X
Food, Water	I, IV, V, VI, VII, VIII, IX X
Health, Sanitation	I, VII, IX, X
Facilities	I, IX

IV. ROAD NETWORK

Factors	Interrelationships
Trafficability	I, II, III, V, VII, VIII, IX X
Accessibility for Military Vehicles	I, II, III, V, VIII, IX, X
Accessibility for Civilian Vehicles	I, II, III, V, VIII, IX, X
Closed by FRG or other Countries	I, II, III, V, VII, VIII

V. RAILROAD NETWORK

Factors	Interrelationships
Regular Schedule	I, II, III, IV, VIII, IX
Interface with Evacuation	I, II, III, IV, VII, VIII, IX
Ports/Points to Other Countries	I, II, III, IV, VIII, IX

VI. AIRCRAFT

Factors	Interrelationships
MAC Resources	I, II, III, VII, VIII, IX, X
CRAF	I, II, III, VIII, IX, X
Commercial Carriers	I, II, III, VIII, IX
Passenger Capacity	I, II, III, IV, V, VIII, IX
Fuel Requirements	II, IV, V, VII
Maintenance Requirements	II, IV, V, IX, X
Passenger Handling Equipment Requirements	II, IX, X
Crew Requirements	II, VIII, IX

VII. SUPPLIES

Factors	Interrelationships
Fuel Reserves	I, II, III, IV, V, VI, VIII, IX
Food	I, II, III, IV, V, VI, VII, VIII, IX
Water	I, II, III, IV, VIII, IX
Medical	I, II, III, IV, V, VI, VIII, IX

VIII. POLITICAL/MILITARY ENVIRONMENT

Factors	Interrelationships
Decision to Implement NEO	I, II, VI, VII, X
Decision to Activate CRAF	I, II, VI, VII, IX, X
Borders of FRG Open/Closed	I, II, III, IV, V, VI, VII, X
State of Alert Readiness	I, II, III, IV, V, VI, VII, X
Enemy Action	I, II, III, IV, V, VI, VII, IX, X

IX. WEATHER

Factors	Interrelationships
Heavy Winter (Snow and Ice) FRG	I, II, III, IV, V, VI, VII, VIII, X
Heavy Fog (FRG)	II, III, IV, VI, VII, VIII
Rain/Flooding (FRG)	I, II, III, IV, V, VI, VII, VIII, X
Storms in North Atlantic	I, II, VI, VII, VIII, X
Heavy Winter (CONUS)	I, VI, VII, VIII, X

X. COMMUNICATIONS NETWORK

Factors	Interrelationships
Transatlantic	I, II, VI, VII, VIII, IX
Intra-theater	I, II, III, IV, V, VI, VII, VIII, IX

APPENDIX C

BERLIN EVACUATION NETWORK

In Chapter III, the Rhein-Main network model was described as receiving approximately 9,000 evacuees from Berlin. There is a projected population of 14,000 noncombatants in Berlin, who will be restricted to an airlift exit via Templehof AB. The scenario referred to throughout this thesis, from The Nuclear Crisis of 1979 (2), projects that Templehof will be overrun or shut down by simulation hour 96.

A Q-GERT network model was developed for Templehof similar to those developed for Rhein-Main and Munich. A listing of the program for the Templehof model is included at the end of this Appendix. The program was run for 100 iterations to develop the distribution of inter-arrival times used between nodes 130 and 132 in Figure 4 of Chapter III.

This research assumed that ten C-130s and two C-141s were used to ferry evacuees between Templehof and Rhein-Main. These figures represent 11 percent and 20 percent, respectively, of each type aircraft considered in-place at the beginning of the Noncombatant Evacuation Operation. The transactions representing evacuees were generated by a source node, then probabilistically assigned by a queue node to branches waiting to board either C-130s or C-141s; activities representing round trip flight times between Berlin and Frankfurt were used to route the transactions to a sink node where inter-arrival times were collected.

The distribution of inter-arrival times was determined to be normal, with a mean of .4014 hours and a standard deviation of .0057 hours. The mean time for the Berlin network to empty was found to be 102.27 hours, or six more than the overrun time. Therefore, the number of Berlin noncombatants reaching Rhein-Main was limited to less than 65 percent of the projected NEO population. It was assumed that surface routes from the city of Berlin would be closed, and the air corridors would remain open for the full 96-hours previously mentioned.

Templehof Program Listing

```
GEN,GULLETT,NEOTRY,4,17,1980,0,2,10000,145.,10.,,0,3* Templehof
SOU,137,0,1,A*
QUE,37,15,,P*
REG,47,5,5,A*
REG,57,1,1,A*
QUE,227,0,3,D,,177*
QUE,207,0,5,D,,197*
REG,177,1,1,D*
REG,197,1,1,D*
REG,67,1,1,D*
REG,87,1,1,D*
QUE,442/AUSBERLIN,0,,D*
ACT,137,137,CO,.75,(9)A1.LT.36*
ACT,137,37,CO,.6,(9)A1.LT.37*
ACT,137,37,CO,.6,(9)A1.LT.37*
ACT,137,37,CO,.6,(9)A1.LT.37*
ACT,137,37,CO,.6,(9)A1.LT.37*
ACT,137,37,CO,.6,(9)A1.LT.37*
ACT,137,37,CO,.6,(9)A1.LT.37*
ACT,37,57,CO,.4,,,.7*
ACT,37,57,CO,.4,,,.3*
ACT,47,227,CO,.1*
ACT,57,207,CO,.1*
ACT,177,227,CO,.5*
ACT,227,67,NO,3,,2*
ACT,207,87,NO,4,,10*
ACT,197,37,CO,.5*
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ACT,67,442*
ACT,67,442*
ACT,67,442*
ACT,67,442*
ACT,67,442*
ACT,87,442*
REG,103,1,1,D*
ACT,103,1*
ACT,442,103*
QUE,24,0,,D*
SIN,1,1,1,D,I*
SIN,3,1,1,D,I*
PAR,1,,3,7*
PAR,2,,5,8*
PAR,3,1.5,1.2,3.5*
PAR,4,2.25,2.0,4.2*
PAR,5,,8,16*
PAR,9,31,27,48*
VAS,137,1,IN,1*
ACT,24,3*
FIN*
```

APPENDIX D

RHEIN-MAIN NETWORK PROGRAM

```
GEN,GULLETT,NEOTRY,4,17,1980,1,3,10000,900.,10.,,0*
        RHEIN-M 208K,336 HRS.
SOU,130,0,1,A*
REG,90,1,1,D*
QUE,230,20,60,D,,330,0,5*
QUE,240,20,60,D,,340,0,5*
QUE,250,20,60,D,,350,0,5*
STA,100,1,1,A,B*
QUE,330,0,,D*
QUE,340,0,,D*
QUE,350,0,,D*
QUE,210,0,3,D,,110*
QUE,220,0,3,D,,120*
QUE,225,0,3,D,,120*
QUE,20,10,30,D,,21* AIRPORT CAPACITIES ARE LIMITED
QUE,21,0,,D,,,0,.25*
ACT,21,20,CO,.4,41/BALKED,1*
QUE,30,0,25,P,,B,0,.1*
REG,40,1,1,A*
REG,50,1,1,A*
REG,110,1,1,D*
REG,120,1,1,D*
REG,60,1,1,D*
REG,80,1,1,D*
ACT,130,90,UN,1,(9)T.LE.96*
ACT,90,230* EACH CONVOY REPRESENTS 720 EVACUEES= ONE C-5A LOAD
ACT,90,230*
ACT,90,240*
ACT,90,240*
ACT,90,250*
ACT,90,250*
ACT,20,30,CO,.1*
ACT,30,40,CO,.5,,.4*
ACT,30,50,CO,.5,,.6*
ACT,110,20,CO,1*
ACT,120,20,CO,1*
ACT,60,1*
ACT,80,1*
ACT,40,210,CO,.1,(9)T.LT.1440*
ACT,50,220,CO,.1,(9)T.LT.120*
ACT,50,225,CO,.1,(9)T.GT.120*
ACT,330,100,UN,5,,1*
ACT,340,100,UN,5,,1*
ACT,350,100,UN,5,,2*
PAR,12,34,28,48*
PAR,9,31,27,48*
PAR,5,,8,16*
PAR,4,2.25,2.0,4.2*
PAR,3,1.5,1.2,3.5*
```

```
PAR,1,,3,7*
SIN,1,1,1,D,B*
SIN,4/TRANSHIP,1,1,D*
ACT,100,20,CO,.125,29/WELCOMEQ,(9)T.LT.900*
ACT,100,4,CO,24,(9)T.GT.336*  FLEE TO RAMSTEIN BY RAIL ALL
                  ELSE IS FALLEN
REG,132,4,4,A*   LIMITS BERLINERS TO APPROX. 9000
ACT,130,132,NO,6,,1,,T.LT.96*
ACT,130,130,CO,1.90,(9)T.LT.96*
ACT,132,20,CO,.25,132/TOTERMAL,(9)T.LT.104*
PAR,6,.4014,.3843,.4185,.0057*
ACT,210,60,NO,9,,10*  40% C-5AS
ACT,225,80,NO,12,,18*  40%
ACT,220,80,NO,12,,9*  40%
PAR,2,,5,8*  SUMMER
ACT,250,100,UN,2,,3*
ACT,240,100,UN,2,,3*
ACT,230,100,UN,2,,3*
FIN
```

APPENDIX E

MUNICH NETWORK PROGRAM

```
GEN,GULLETT,NEOTRY,4,17,1980,3,3,10000,900.,10.,,0*
                        MUNICH, 122K 120 HRS
SOU,130,0,1,A*
REG,90,1,1,D*
QUE,230,20,60,D,,330,0,5*
QUE,240,20,60,D,,340,0,5*
QUE,250,20,60,D,,350,0,5*
QUE,330,0,,D*
QUE,340,0,,D*
QUE,350,0,,D*
QUE,220,0,3,D,,120*
QUE,20,10,30,D,,21* AIRPORT CAPACITY=(600 X 30)+(25 X 600)
                        ALL OTHERS BALK
QUE,21,0,,D,,B,0,1*
ACT,21,20,CO,1,,1*
QUE,30,0,25,P,,B,5,5*
REG,50,1,1,A*
STA,100/ARRCONVS,1,1,A,B*
REG,80,1,1,D*
REG,120,1,1,D*
ACT,130,90,UN,1,(9)T.LE.96*
ACT,90,230*
ACT,90,230*
ACT,90,240*
ACT,90,240*
ACT,90,250*
ACT,90,250*
ACT,130,130,CO,3.6125,(9)T.LT.96*
ACT,20,30,CO,.125,20/PROCESS,1*
ACT,30,50,CO,.5,(8).4*
ACT,30,50,CO,.5,(8).6*
ACT,120,20,CO,1*
ACT,80,1*
ACT,80,2*
ACT,220,80,NO,12,,*
ACT,330,100,UN,5,,1*
ACT,340,100,UN,5,,1*
ACT,350,100,UN,5,,2*
ACT,100,6,(9)T.GT.120*TRANSHIPMENT TO ALTERNATE AIRFIELD ALL
                        OTHER CAPTURED
ACT,50,220,CO,.125,(9)T.LT.120*
ACT,100,20,CO,.125,29/WELCOMEQ,(9)T.LT.900*
PAR,12,34,28,48*
PAR,5,,8,16*
PAR,2,,5,8*SUMMER
PAR,1,,3,7*
STA,1,1,1,D,B*
SIN,2,1,1,D,I*
ACT,50,225,CO,.125,(9)T.GT.120*
```

```
SIN,6,1,1,D,F*
ACT,1,2*
ACT,230,100,UN,2,,5*
ACT,240,100,UN,2,,5*
ACT,250,100,UN,2,,5*
FIN
```

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